W. B. No. 809

U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU

MONTHLY WEATHER REVIEW

VOLUME 51, No. 6

JUNE, 1923

WASHINGTON
GOVERNMENT PRINTING OFFICE
1923

JUNE, 1923.

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† In marine separate.

WEATHER OF THE MONTH.

CHARTS.

MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

VOL. 51, No. 6.
W. B. No. 809.

JUNE, 1923.

CLOSED AUGUST 3, 1923
ISSUED SEPTEMBER, 1923

RAINFALL INTERPOLATION.

By ROBERT E. HORTON, Consulting Hydraulic Engineer.

[Voorheesville, N. Y., July 10, 1924.]

INTRODUCTION.

In the application of rainfall records to any purpose it is always desirable and often indispensable that the record should be complete. Interpolation of rainfall may be required for a variety of purposes:

1. To fill in a missing record for one or more months.
2. To fill in records for one or more years.
3. For the determination of the rainfall in a single shower or for a certain day or for a particular storm.
4. To find the rainfall at a given location where no record has been kept, either the mean being required or the rainfall for a given period, storm, day, or shower.

In general the accuracy of the result increases with the length of the period for which interpolation is made. The rainfall for a year can usually be interpolated with a smaller percentage of error than rainfall for a month and this, in turn, can be interpolated more accurately than the rainfall for a storm, day, or shower. In the adoption of methods for interpolation of missing rainfall values the labor involved as well as the accuracy attainable must be considered. Methods of interpolation which are simple and which give excellent results when applied to the determination of missing annual or monthly values may and usually will not be equally well adapted to the interpolation of missing values for a given storm, day, or shower.

The determination of the rainfall amount at a given place in a given storm, day, or shower forms a separate problem, especially in case where no records whatever have been kept at the location in question. The present discussion is confined to the problem of determining missing rainfall values at locations where some records exist, either antecedent or subsequent to the missing interval, or both. It is in the form of monthly results that rainfall data are most often published and used and the completion of annual records often involves supplying data for missing months only. Anyone having occasion to use the rainfall records in a given locality will do well to make the necessary interpolations in a careful and reliable manner in the first instance of their application, thus rendering the records available in complete form for future use without further labor.

This discussion is confined to interpolation at the location of an existing rain-gage station. In all such cases there are some records at the location for which data are required, which may serve as guides to interpolation for the missing intervals.

Missing months within the body of a rainfall record are the result of three principal causes:

1. Absence or illness of observer.
2. Accidents to the rain gage or record.
3. Changing of observers.

Methods of interpolating missing records may be classified as follows:

1. Those dependent on records at the same station only.
a. The normal method.
b. Mean of preceding and following months.
c. Mean of the same month in preceding and following years.
d. Angot's method.
2. Methods depending on contemporaneous records at surrounding stations alone.
a. Substitution of the record for the nearest station.
b. Mean of three surrounding stations.
c. Inclined plane method.
3. Methods utilizing data for both the station of interpolation and for surrounding stations.
a. Fournie method.
b. Fournie-Horton method.
c. Abnormality method.
d. Angot-Horton method.
e. Angot-Leach method.

Some of these methods make use of contemporaneous records only, i. e., those at surrounding stations for the month or year to be interpolated, or those for the next preceding and following months, or years. Contemporaneous methods include:

1–*b.* Mean of preceding and following months.
1–*c.* Mean of same month in preceding and following years.
2–*a.* Nearest station method.
2–*b.* Mean of three surrounding stations.
2–*c.* Inclined plane method.
3–*d.* Correction ratio method.

Other methods require the use of monthly or annual normals or long term means at one or more stations. These include:

1–*a.* The normal method.
1–*d.* Angot method.
3–*a.* The Fournie method.
3–*b.* Fournie-Horton method.
3–*c.* The abnormality method.
3–*d.* Angot-Horton method.
3–*e.* Angot-Leach method.

CORRELATION AT ADJACENT STATIONS.

It would be expected that the accuracy obtainable in the use of the precipitation at one station for the determination of the precipitation at an adjacent station would depend to some extent on the degree of correlation between recorded rainfall amounts at the two stations. Selecting a group of stations in California with marked seasonal rainfall so as to eliminate uncertainties at the end of the hydrologic year, the coefficients of correlation

of the seasonal total rainfall between adjacent stations were found as follows:

Correlation of seasonal total rainfall between adjacent stations.

	Years, incl.	K_e
North Bloomfield and—		
Grass Valley, Calif.	1873–74 to 1885–86; 1895–96 to 1903–04	0.808
Iowa Hill, Calif.	1879–80 to 1885–86; 1895–96 to 1908–09	0.864
Bowman Dam, Calif.	1899–1900 to 1908–09	0.620
Blue Canyon, Calif.	1889–90 to 1908–09	0.770
Nevada City, Calif.	1889–90 to 1908–09	0.930
Towle, Calif.	1895–96 to 1901–02	0.671
Truckee, Calif.	1871–72 to 1885–86; 1895–96 to 1908–09	0.626
Cisco, Calif.	1871–72 to 1885–86; 1895–96 to 1908–09	0.716
Cisco, Calif.	1900–01 to 1908–09	0.645

The location of the stations are shown on Figure 1. The coefficients are relatively high.

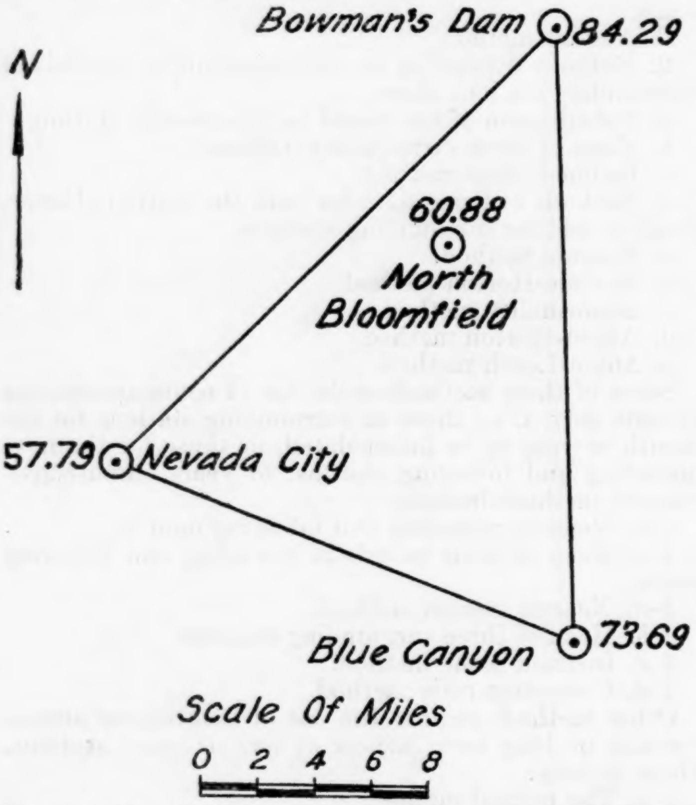

FIG. 1.—Location of rainfall stations, California group. (Figure gives mean annual rainfall.)

The correlation between monthly rainfall amounts may, however, be different from that between the seasonal totals. Monthly coefficients were worked out for 12 months selected at random, one month from each of 12 years for 6 pairs of stations, the locations being shown in Figures 1 and 2.

Correlation coefficients for adjacent stations for 12 calendar months selected at random.

North Bloomfield, Calif., and Bowman's Dam, Calif.	0.98
North Bloomfield, Calif., and Blue Canyon, Calif.	0.93
North Bloomfield, Calif., and Nevada City, Calif.	0.994
New Iberia, La., and Lafayette, La.	0.744
New Iberia, La., and Abbeville, La.	0.75
New Iberia, La., and Franklin, La.	0.87

CORRELATION OF RAINFALL IN CONSECUTIVE MONTHS OR YEARS.

In view of the convenience of using the record for preceding and subsequent intervals at the interpolation station as a basis for rainfall interpolation, it is of interest to determine the extent of correlation between rainfall amounts in a given month or year and in the corresponding intervals for preceding and subsequent years. The rainfall for the month of April at Albany, N. Y., is shown graphically on Figure 3 in comparison with the mean precipitation for the preceding and following months. The calculated correlation coefficients between the rainfall on a given month at Albany and the mean of the preceding and following months are as follows:

Correlation of coefficients between a given month and the mean of the preceding and following months.

(Albany, N. Y., 1874–1915, 42 years.)

April	−0.0539
July	+0.1004
November	+0.194

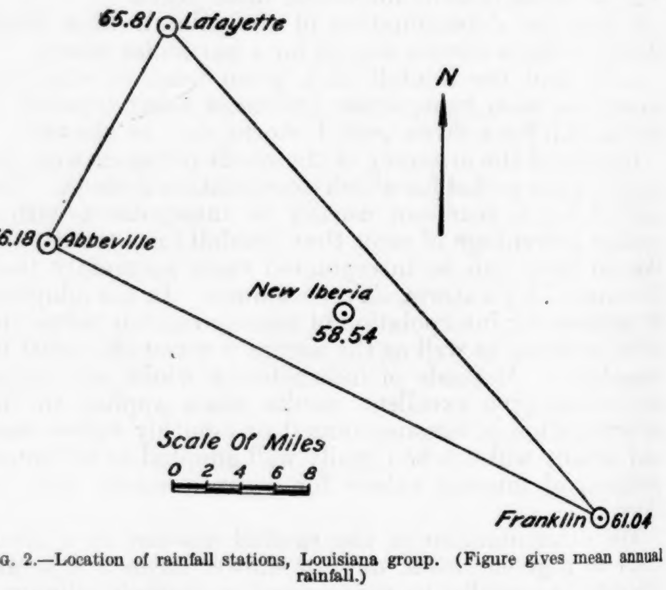

FIG. 2.—Location of rainfall stations, Louisiana group. (Figure gives mean annual rainfall.)

The coefficients are lower than in the case of correlation between simultaneous intervals at adjacent stations.

Hessling [1] found the correlation between different pairs of months as to rainfall and temperature, respectively, for 24 stations in the corn region of Argentina, as follows:

In some cases there is a fair degree of correlation for rainfall but in general it is less than for temperature.

Months correlated.	K_e Precipitation.	K_e Temperature.
October-November	0.22	0.63
October-December	0.48	0.18
October-January	0.07	0.53
November-December	0.29	0.56
November-January	0.03	0.51
December-January	0.33	0.50

[1] Relation between the rainfall, the temperature, and the yield of corn in Argentina. MO. WEATHER REV., Oct., 1921, 49:545.

Peck and Snow [2] have determined the correlation between the rainfall of each month of the year in England

[2] The correlation of rainfall, *Quar. Jour. Roy. Met. Soc.*, Oct. 1913, pp. 307-316.

and that of the remaining 11 months, for each of four years, 1908 to 1911, with the following results:

Coefficients of correlation of the rainfall of each month with that of the remaining months of the year.

(Mean for four years 1908-1911.)

January	+0.31	July	0.00
February	+0.15	August	+0.15
March	+0.29	September	+0.12
April	+0.20	October	+0.25
May	+0.15	November	+0.19
June	+0.04	December	+0.25

Here again the coefficients are relatively low; in fact, there is no appreciable correlation between the rainfall of the summer months in England and that of the remainder of the year. This is probably the effect of thunderstorms in these months, whereas cyclonic and orographic rain predominates in the remaining months of the year. The correlation coefficients between rainfall in a given year in England and that in the preceding and following years have also been determined by Peck and Snow. Here the resulting coefficients are relatively much larger than those obtained for single months compared with the preceding and following months. This indicates that the use of the measured precipitation for the preceding and following years at a given station may be much more reliable as a means of interpolating annual than monthly rainfall.

Correlation coefficients showing the relation of rainfall in a given year to that in the preceding and following year.

	1908	1909	1910	1911
1908	+1.00	+0.69	+0.70	+0.57
1909	+0.69	+1.00	+0.75	+0.64
1910	+0.70	+0.75	+1.00	+0.71
1911	+0.57	+0.64	+0.71	+1.00

From a study of long term rainfall records at Greenwich, Glasgow, Greenock and Dundee, Russell [3] found that the coefficients of correlation between rainfall amounts in successive months were always below 0.50.

The average correlation coefficient for the 48 pairs of monthly cases at the four stations is near zero. There were 17 cases of negative and 31 cases of zero or plus coefficients. For the pairs of winter months, November and December to January and February, inclusive, there are consistent positive correlations following an average value of about 0.25. In general the results indicate that there is but little positive correlation between rainfall amounts for two successive years at the same station, especially during the summer season.

MONTHLY RAINFALL INTERPOLATION.

There are two principal conditions under which the interpolation of monthly rainfalls may be required:

1. To fill in gaps within the record at a given station, the previous and subsequent records both being available.
2. Extrapolation to extend a record so as to make it complete for a chosen period.

Both these cases are here considered under the general term "interpolation." In general (with one exception), methods applicable to the first case are also applicable in the case of extrapolation, and the accuracy obtainable in the two cases is usually about the same. There are often some months missing from otherwise excellent rainfall records. Obviously a record for 20 years, containing say 10 missing months scattered through 5 different years, is better if completed than if only the 15 complete years are utilized. The record when completed represents actual observations for 19 years and 2 months, and even should there happen to be considerable error in the interpolation of the remaining 10 months, the resulting mean for 20 years is likely to be nearer to the true long term mean than is the mean for the 15 complete years only. It is not infrequently the case that one or more months are missing from almost every year, even where such a fragmentary record is the only one available, and the choice lies between discarding the record altogether, or in some way completing it.

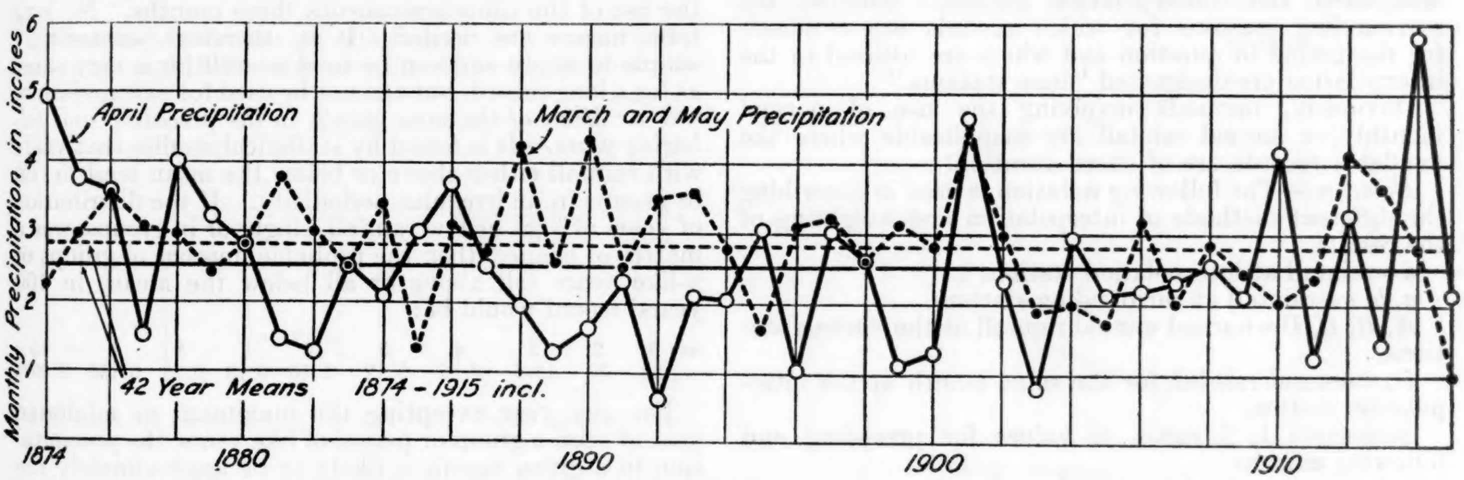

FIG. 3.—Relation between April rainfall and mean of preceding and following months. Albany, N. Y., 1874-1912, inclusive.

Relation curves between the rainfall amounts at adjacent stations can be derived if fairly long records are available for both stations. The accuracy of most interpolation methods depends on the relation between the precipitation at adjacent stations.

Having given the monthly relation curve between two stations and the precipitation at the base station, corresponding precipitation shown by the relation curve gives a value of the quantity to be interpolated. If relation curves are available for three base stations the mean of the three resulting interpolated values may be used. This is perhaps the most rational of all methods of rainfall interpolation, especially if three stations are used and the three results are given weights dependent on the relative distances of the base stations from the interpola-

[3] *Quar. Jour. Roy. Met. Soc.*, July, 1922, p. 225.

tion station. If interpolations are required in different months of the year, then the use of this method involves the derivation of a rainfall relation curve for each month for which interpolations are to be made, and if three base stations are used three sets of curves are necessary. The labor of using the method for monthly values is so excessive that it has not been given further consider ation.

In case of the interpolation of annual rainfall amounts only one relation curve is required between the interpolation station and each of the base stations. The method is therefore much better adapted to interpolation of annual than of monthly rainfall.

In discussing multiple station methods the use of three surrounding stations is mainly considered, this being the most usual case. Instances will, however, arise where only one or two adjacent station records are available and others where there are four equally applicable. Adaptation of the methods described to these special conditions will be readily perceived. If there is choice of stations, those having the highest correlation with the station for which interpolation is to be made should be selected.

The station for which interpolation is required is designated the "interpolation station," whereas the surrounding stations for which records are available for the period in question and which are utilized in the interpolation are designated "base stations."

Obviously, methods involving the use of normal monthly or annual rainfall are inapplicable where the available records are of short duration.

Notation.—The following notation is used in describing the different methods of interpolation and weighting of the results.

d = rainfall at interpolation station.

a, b, c = rainfall at surrounding stations.

A, B, C, D = normal annual rainfall at the various stations.

D_n = normal rainfall for the same month at the interpolation station.

Subscripts 1, 2, relate to values for preceding and following months.

Subscripts p, f, relate to values for the same month in the preceding and following years.

X_a, X_b, X_c = distances of base stations from the interpolation station.

W_a, W_b, W_c = relative weights of results derived from stations a, b, and c.

Characteristics of the different methods are as follows:

1–*a. Normal method.*—This consists in substituting the mean rainfall for a given month as determined from the longest available record at the interpolation station. Obviously the normal method can only be used where the station has been maintained long enough to give fairly good normals for the different months. In applying this method no effort is made to take into account the abnormality of the rainfall for the month to be interpolated. At the same time, if a large number of months are missing from a record, substitution of the normal values in place of the actual, which are unknown, will give theoretically the same mean for the whole record as if the actual values had been utilized. There is, however, no reason for belief that the rainfall for a particular month agrees in any close degree with the normal for that month, and since some information may generally be obtained as to the abnormality of the precipitation in any particular month, this method must be considered as not conforming to the requirement of making the best use of the available information.

As regards annual results the error in the mean resulting from the substitution of the normal for the actual precipitation in any one year decreases as the length of record increases.

If r is the ratio of the actual rainfall in the given year to the mean,

$$\frac{\text{Apparent mean, } N \text{ years}}{\text{true mean}} = \frac{N-1+r}{N}$$

This becomes unity if the ratio r is unity.

1–*b. Mean of preceding and following months.*—If the precipitation in a given month is abnormally high, the mean of the preceding and following months is rather likely to be high, and vice versa. Again, if the precipitation varied uniformly from month to month, the mean for any month would be equal to the mean of the preceding and following months. The precipitation does not, however, vary in a uniform manner, and the mean of the preceding and following months will generally be less than the true precipitation for the maximum month of the year or season and too large for the minimum month of the year or season. This method has the advantage that it is based solely on records at the station of interpolation, and, furthermore, requires only the use of the contemporaneous three months. No long term means are needed. It is, therefore, exceedingly simple to apply and can be used as well for a very short as for a long record, but can not be used for extrapolation.

1–*c. Mean of the same month in the preceding and following years.*—It is found by statistical studies that years with rainfall either above or below the mean tend to run in groups in an irregular periodicity. If the distribution of years of high or low rainfall, singly or in groups, was a matter of chance, then the probable number of groups of n-like years (all above or all below the mean) in 100 years' record would be:

n=	1	2	3	4	5	6	7	8	9	10
	50	25	12.5	6.25	3.12	1.56	0.78	0.39	0.195	0.0925

For any year excepting the maximum or minimum year of such a group or period of like years, the precipitation in a given month is likely to be approximately the mean of that for the same month in the preceding and following years. This method is subject to the same errors and limitations as to the use of the mean of the preceding and following month, and it can not be used for extrapolation. In general it gives better results when the missing months fall in a group of several like years than when they fall in an isolated year. In the latter case if the true value for the missing month is high, the corresponding months in both preceding and following years are likely to be low and vice versa. For this condition the mean of the same months in preceding and following years may be seriously in error.

1–*d. Angot method.*—Angot developed what are known as pluviometric coefficients; these are essentially the ratios of the precipitation amounts in the different months to the yearly total. These in general are more nearly constant for a given month than is the actual monthly precipitation. This would be expected since, for example, an excessive precipitation in a given month adds to the yearly total and vice versa, in both cases resulting in a tendency to maintain constancy in the pluviometric coefficient.

Similarly the pluviometric coefficients at adjacent stations are generally more nearly equal than are the actual rainfall amounts. The use of pluviometric coefficients for the base or for surrounding stations should apparently afford a reliable method of interpolation. Unfortunately, the true Angot pluviometric coefficient

can not be determined at the interpolation station for the year in which interpolation is to be made, since the record is wanting for at least one month. A modified coefficient can be used. Expressing the normal ratio of precipitation in the missing month to the total normal precipitation in the remaining 11 months by C'', then if $\Sigma P''$ is the total precipitation in the remaining 11 months of the given year, the precipitation for the missing month could be estimated by the formula,

$$P = C'' \Sigma P''$$

This method would, however, be very laborious. It has accordingly been modified, probably at some sacrifice of accuracy, by using instead of C'' the ratio

$$C = \frac{D}{D_1 + D_2}$$

or the ratio of the normal for the missing month to the mean of the normals for the preceding and following months; then

$$d = C\frac{d_1 + d_2}{2}$$

This method is similar to the use of the mean of the preceding and following months but a correction is

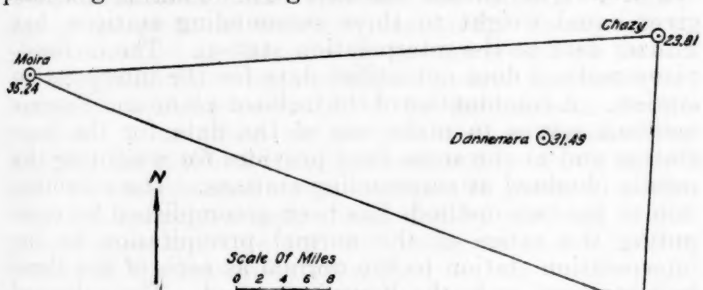

FIG. 4.—Location of rainfall stations, New York group. (Figure gives mean annual rainfall.)

made for the unequal rate of variation of rainfall from month to month. The method is wholly dependent upon records at the station of interpolation. It is less laborious than methods utilizing long term means for surrounding stations, but is in general more laborious than any of the methods described dependent on contemporaneous records alone, although if a large number of values is to be interpolated, the work by either this or the other methods involving long term means is proportionally decreased as compared with the case where only a small number of interpolations is required, since the monthly means once determined answer for all the interpolations. Frequently the monthly means are available at the outset. This method can, of course, be applied to three surrounding stations, but it then becomes more laborious than Fournie's method without any apparent advantages.

2–*a*. *Nearest station*.—The substitution of the record at the nearest adjacent station for a missing monthly record is not an uncommon procedure. It is perhaps the simplest of all methods of obtaining a value to fill out a missing month. There is generally a fairly good correlation between monthly precipitation at adjacent stations. The correlation, however, might be perfect and yet the values for one station be widely different from those for the other, owing to a constant difference which does not appear in the correlation coefficient. This source of error is eliminated by the use of Angot's pluviometric coefficients (method 2–*d*). Where the means for the two stations are substantially the same, direct substitution of the value for the nearest station frequently gives good results for closely adjacent stations. If, however, there is no single closely adjacent station, but if there are several nearly equidistant but more remote stations, the use of the precipitation at the nearest station alone is not justified. The method can be applied either to interpolation or extrapolation, and since it does not require the determination of a mean, it can be applied to a short as well as to a long record.

2–*b*. *Mean of three surrounding stations*.—This method should theoretically have a much greater accuracy than the use of the nearest station alone. Furthermore, since surrounding stations on different sides of the interpolation station are to be used, the effect of local storms which may occur at one station but not at another is more likely to be taken into account. It involves but little labor and has all the other advantages of the use of the nearest station record.

2–*c*. *Inclined-plane method*.—This method was devised by the author with a view to applying simultaneous or or contemporaneous records in the most logical manner possible, thus obtaining the best practicable result with

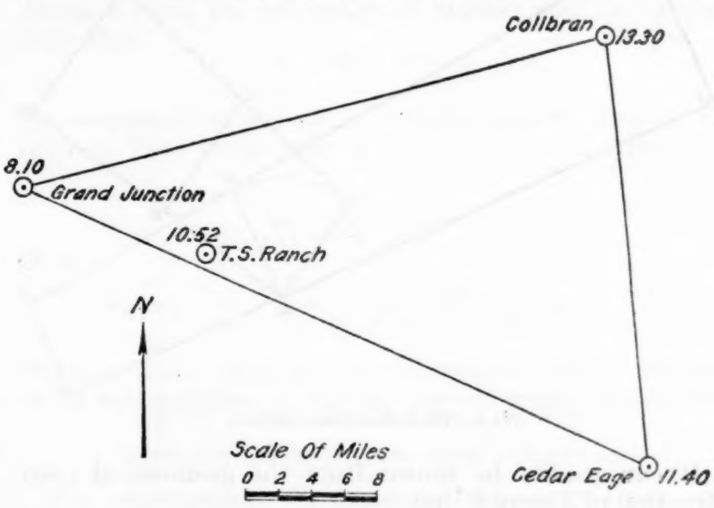

FIG. 5.—Location of rainfall stations, Colorado group. (Figure gives mean annual rainfall.)

the least expenditure of labor, since all methods dependent on simultaneous or contemporaneous records alone are much simpler of application than methods involving the use of long-term means. It depends upon the principle that the position of a plane is completely determined by the coordinates of three points in the plane. In the absence of information to the contrary, the best assumption which can be made is that rainfall varies uniformly between adjacent stations.

Select three base stations, A, B, C, Figure 6, surrounding the interpolation station. On a suitable map showing the relative positions of the stations, connect any pair, A, B, of the base stations by a line, and erect perpendiculars to this line at the two stations, and measure off on each perpendicular a length proportional to the precipitation at that station for the period to be interpolated. On the assumption of uniform variation, the precipitation at any point along this will be proportional to the ordinate from the base line to the line connecting the two plotted points. Draw another line from the third base station, C, through the interpolation station, D, intersecting the base line AB at E. Erect a

perpendicular to AB at E, intersecting the line FG at H. The precipitation at E is assumed to be proportional to EH. Draw perpendiculars to CE, one at C proportional to the precipitation at that station, and one at B equal to EH. Connect these by a line JK. Then a perpendicular DL at the interpolation station will have a length proportional to the precipitation at D. The graphical construction is extremely simple. Only simultaneous records are used and the method involves but little more labor than the use of the mean of the three surrounding stations, but it is more logical. The direct use of the mean of three surrounding stations gives equal weight to each of the stations, although they may be at widely different distances from the interpolation station. The weight given to remote stations in the inclined-plane method decreases as the distances increases.

The inclined plane method of combining the results of data for surrounding stations can also be used in conjunction with the Fournie and other multiple station methods. It is to be considered, therefore, as a principle rather than as being restricted to the narrow limits of a method of interpolation.

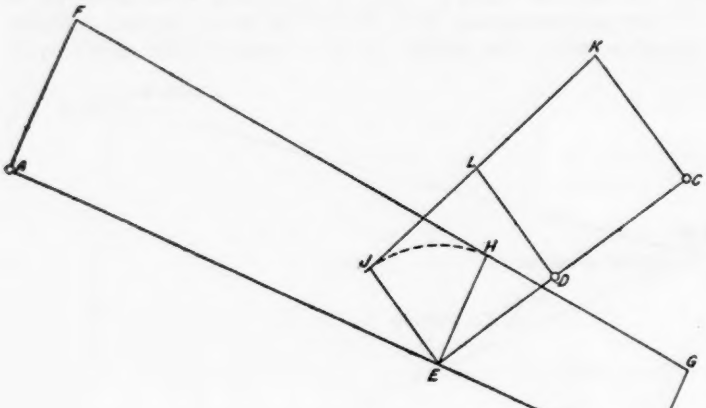

FIG. 6.—The inclined-plane method.

It can readily be shown from the geometrical construction of Figure 6 that—

$$P_d = K_1 P_a + K_2 P_b + K_3 P_c$$

where

$$d_1 = \frac{AE}{AB},\ d_2 = \frac{ED}{EC},\ \text{Figure 6,}$$

and

$$K_1 = 1 - d_1 - d_2 + d_1 d_2$$

$$K_2 = d_1 - d_1 d_2,\ K_3 = d_2;$$

also

$$K_1 + K_2 + K_3 = 1$$

or the sums of the coefficients is unity, providing an easy check on computations.

3–*a*. *Fournie method.*—This method has been extensively used for interpolation of missing rainfall years. It is equally applicable to the interpolation of missing months, but like all other methods, gives less accurate results for monthly than for annual interpolations, owing to the relatively greater variability of rainfall for short periods than for full years. To apply this method, three surrounding stations are selected for each of which there is a rainfall record for a period of several years simultaneous with the rainfall record at the interpolation station. Calling means for these three stations A, B, and C, and calling the mean for the interpolation station D, the ratios $\frac{D}{A}$, $\frac{D}{B}$, and $\frac{D}{C}$ are worked out for the simultaneous periods covered by all four records. Calling the actual precipitations at the three base stations for the period for which interpolation is required a, b, and c, respectively, these values are multiplied by the corresponding ratios and the mean of the three products taken as the interpolated rainfall for the interpolation station. The method is laborious, especially in view of the fact that in many cases gaps will be found in the records for the base stations which must themselves be filled out before long-term ratios can be computed. Sometimes one of the base stations chosen is necessarily much more remote from the interpolation station than are the others. Fournie's method gives equal weight in the result to the values obtained from the different base stations, whereas it is likely that the precipitation for the given month at the interpolation station conforms more closely to that at a nearby station than to that at a remote station. Obviously the Fournie method can only be applied where records have been kept for a number of years. It does not depend on contemporaneous records and considerable research is often necessary to compile the data for computing the ratios of the means, even where the records for the base stations are complete.

3–*b*. *Fournie-Horton method.*—The Fournie method gives equal weight to three surrounding stations, but utilizes data at the interpolation station. The inclined-plane method does not utilize data for the interpolation station. A combination of the inclined-plane and Fournie methods serves to make use of the data for the base station and at the same time provides for weighting the results obtained at surrounding stations. The combination of the two methods has been accomplished by computing the ratios of the normal precipitation at the interpolation station to the normal at each of the three base stations, as in the Fournie method. The values of these three ratios are plotted by the inclined plane method and a correction factor obtained, which is applied to the precipitation determined by the inclined plane method from simultaneous records at three surrounding stations. This involves two applications of the inclined-plane method for each calculated interpolation. An adaptation of this method, simpler and apparently equally good, consists in first determining the three values of d from the Fournie ratios $\frac{D}{A}a$, $\frac{D}{B}b$, $\frac{D}{C}c$ and then applying the inclined plane method to these values to determine the interpolation value.

3–*c*. *The abnormality method.*—The abnormality method is based on the departure of the precipitation at adjacent stations from the normal or mean precipitation for the month to be interpolated. The normal precipitation for the given month is first determined for the base stations and the ratio between the actual precipitation and the mean is then found for each of these stations. This ratio indicates the departure from the mean, or the abnormality for the month to be interpolated. The precipitation at the interpolation station is found by multiplying the normal rainfall for the same month at this station by the direct or weighted mean of the abnormality ratios for the base stations.

The disadvantages of this method lie in the necessity of having long-time records at adjacent stations and in the labor involved in computing the means.[4]

[4] This method in reality is identical with the Fournie method, the only difference being in the order in which the computations are made.

3-*d*. *Correction-ratio method.*—This method was devised in order to utilize the data for surrounding stations and at the same time give the data for the base station the greatest possible weight, and yet base the interpolation wholly on contemporaneous records so as to avoid the labor of methods dependent on long-term means. It consists in computing the ratios of the actual rainfall at each base station for the month to be interpolated to the sum of the rainfall amounts for the preceding and following months at the same stations, giving three coefficients similar to the single coefficient used in the Angot method. The factors so obtained take into account the abnormality of the precipitation for the month to be interpolated, both as a result of non-linear variation in the rainfall at the interpolation station and also as a result of any local abnormalities of this particular month. The direct or weighted mean of these coefficients is then applied to the sum of the precipitation for the preceding and following months at the interpolation station.

Expressed symbolically,

$$C_a = \frac{a}{a_1 + a_2}, \quad C_b = \frac{b}{b_1 + b_2}, \quad C_c = \frac{c}{c_1 + c_2}$$

Then if these coefficients have weights $w_a + w_b + w_c = 1$

$$P = (C_a \ W_a + C_b \ W_b + C_c \ W_c)\ (d_1 + d_2)$$

3-*e*. *Horton method.*—This method consists in computing the ratios of the precipitation for the month to be interpolated to the sum of the precipitations in the preceding and following months at each of the three surrounding stations precisely as in the correction-ratio method. A weighted mean ratio is then obtained by applying the inclined-plane method to these three values, and the interpolated value equals the product of the weighted correction ratio multiplied by the sum of the precipitation amounts for the preceding and following months at the interpolation station.

3-*f*. *Leach method.*—This is the same as the preceding except that the weights given in the three correction ratios are taken in inverse proportion to the relative distances of the base stations from the interpolation station. It will be noted that the last three methods described all depend in part on the correlation between rainfall amounts in successive months at a given station, and this correlation, as already shown, is frequently small. These methods, however, depend in a much larger degree on the correlation between rainfall amounts at adjacent stations in the corresponding months, and this is usually fairly large.

METHODS OF WEIGHTING INTERPOLATED VALUES.

In applying the methods of interpolation where several surrounding stations are used, each station yields in general a value of the interpolated quantity. These may be given equal weights, in which case the adopted value of the interpolated quantity is the arithmetic mean of the several (usually three) values, or the individual values may be given weights, depending on the locations of the stations or their similarity. In general when three base stations are used, if W_a, W_b, and W_c are the weights assigned to the interpolated values, these weights being chosen relative to such a scale that $W_a + W_b + W_c = 1$, then $d = W_a \ d_a + W_b \ d_b + W_c \ d_c$.

These weights may be arrived at by several methods—

(*a*) By judgment.

(*b*) Inversely as the relative distances of the base stations from the interpolation station.

(*c*) The inclined-plane method.

Weighting by judgment.—Theoretically this is perhaps the best method if properly applied, since it is possible in using it to take into account not only the relative positions of the stations, but the nature, if known, of the rainfall variation between them, and the differences in rainfall causes applying to each.

Consider, for example, an interpolation station on the plains near the foot of a mountain range, with three interpolation stations, two on the plains and one on the mountains. Now suppose the conditions are such that a large proportion of the rainfall on the plains is convective, while at the mountain station the rainfall is more largely orographic. Obviously the plains stations should be given greater weight than the mountain station, if all were equidistant from the interpolation station. Among disadvantages of weighting by judgment are—

(1) The factors affecting the proper weights to be applied are, except relative distances, in general unknown, or not quantitatively known; therefore,

(2) Different operators using the same data will not obtain the same results.

Weighting by inverse distances.—If X_a, X_b, X_c, are the distances of the base stations from the interpolation station, in any linear units, then if weights are assigned to the three stations each inversely proportional to its distance from the interpolation station and on such a scale that

$$W_a + W_b + W_c = 1$$

the numerical values of the weights can be derived as follows: Take reciprocals of X_a, X_b, and X_c. Let

$$\frac{1}{X_a} + \frac{1}{X_b} + \frac{1}{X_c} = M$$

then

$$W_a = \frac{1}{M X_a}, \quad W_b = \frac{1}{M X_b}, \quad W_c = \frac{1}{M X_c}.$$

These relative weights once determined can be applied to all interpolations involving a given group of stations.

SUMMARY OF INTERPOLATION FORMULAS.

For convenience reference the various methods are summarized in analytical form as follows:

(1-*a*) Normal method, $d = d_n$.

(1-*b*) Mean of preceding and following months—

$$d = \frac{d_1 + d_2}{2}$$

(1-*c*) Mean of same month in preceding and following years—

$$d = \frac{d_p + d_f}{2}$$

(2-*a*) Nearest station, $d = a$, b or c, as the case may be.

(2-*b*) Three surrounding stations. For equal weights,

$$d = \frac{a + b + c}{3}$$

or in general—

$$d_a = a, \ d_b = b, \ d_c = c$$

(3-*a*) Fournie's method—

$$\text{Let } r_a = \frac{D}{A}, \ r_b = \frac{D}{B}, \ r_c = \frac{D}{C}$$

For equal weights—

$$d=(r_a a+r_b b+r_c c)/3$$

or in general—

$$d_a=r_a a,\ d_b=r_b b,\ d_c=r_c c$$

(1–*d*) Angot method.

$$d=\frac{D}{D_1+D_2}(d_1+d_2)$$

(3–*c*) Abnormality method, equal weights.

$$d_a=\frac{a}{A}D,\ d_b=\frac{b}{B}D,\ d_c=\frac{c}{C}D$$

(3–*d*) Correction ratio method.

$$C_a=\frac{a}{a_1+a_2},\ C_b=\frac{b}{b_1+b_2},\ C_c=\frac{c}{c_1+c_2}$$

$$d=(C_a+C_b+C_c)\quad(d_1+d_2)$$

or in general—

$$d_a=\frac{C_a}{d_1+d_2},\ d_b=\frac{C_b}{d_1+d_2},\ d_c=\frac{C_c}{c_1+c_2}$$

METHODS OF WEIGHTING.

For three stations with weights $w_a+w_b-w_c=1$.

$$d=d_a\ w_a+d_b\ w_b+d_c\ w_c$$

Weights by inverse distance ratios.

$$w_a=\frac{1}{M\,X_a},\ w_b=\frac{1}{M\,X_b},\ w_c=\frac{1}{M\,X_c}$$

where

$$M=\frac{1}{X_a}+\frac{1}{X_b}+\frac{1}{X_c}$$

Weights by inclined plane method.

$$W_a=K_1=1\ -d_1-d_2+d_1\ d_2$$
$$W_b=K_2=d_1-d_1\ d_2$$
$$W_c=K_3=d_2$$

EXAMPLES OF MONTHLY RAINFALL INTERPOLATION.

In order to compare the different methods, the labor involved in applying them, and their relative values and accuracy, a series of examples was first chosen to which each of the methods described has been applied. These examples were selected to represent four different regions with conditions covering as nearly as possible the range of variation in amount and distribution of rainfall in the United States. The locations of the four groups of stations are shown on Figures 1, 2, 4 and 5.

1. Eastern interior type: Represented by Dannemora, N. Y. Moderate rainfall, quite uniformly distributed throughout the year; variability low.

2. Tropical type: Heavy rainfall, quite uniformly distributed throughout the year but with medium variability, represented by New Iberia, La.

3. Arid type: Very light precipitation, somewhat irregularly distributed; high variability. Represented by T. S. Ranch, Colo.

4. Concentrated seasonal precipitation, or monsoon type: Heavy precipitation during winter months (mostly snow), little or none during certain summer months; high variability. Represented by North Bloomfield, Calif.

The stations chosen include extreme conditions as to snowfall amount and rainfall variability and are probably susceptible to less accurate interpolation of records than the average for central and eastern United States.

In order to test the different methods, a series of 12 months was selected from the record for each station referred to, the selection being made at random, but so that the months chosen for interpolation were not consecutive. Care was taken to secure stations for interpolation such that the complete records were available for the period covered by the interpolations at each of three nearby surrounding stations.

The results obtained by the 12 methods of interpolation used are given in the accompanying Table 1. The first column for each method shows the 12 interpolated values. The second column for each method gives the actual errors in inches. Footings of the columns give the average arithmetic error of the monthly interpolations and the total algebraic error of the 12 interpolations for each station and method.

The comparative results by different methods for each interpolation station are summarized in Table 2. The first section shows the average arithmetic error per month in inches, and the second section the average algebraic error per month in inches.

The average results in inches and also percentages of the true monthly precipitation are further summarized in Table 3. Methods using contemporary records at surrounding stations give much smaller arithmetic error than the simpler methods using data for the interpolation station only, but there is not much difference between the two groups of methods as regards algebraic error, since most methods in both groups involve constant errors due to differences between the means at the interpolation station and the base stations.

TABLE 1.—*Comparison of methods of interpolating missing monthly precipitation records.*

Month and year.	Actual precipitation, inches.	1-a. Normal method.		1-b. Mean of preceding and following months.		1-c. Mean of same month preceding and following year.		1-d. Angot method.		2-a. Nearest station.		2-b. Mean of three surrounding stations.		2-c. Inclined plane.		3-a. Fournie method.		3-b. Fournie-Horton method.		3-c. Abnormality method.		3-e. Horton method.		3-f. Leach ratio.	
		Value.	Error.	Value.	Error.	Value.	Error.	Value.	Error.	Value.	Error.	Value.	Error.	Value.	Error.	Value.	Error.	Value.	Error.	Value.	Error.	Value.	Error.	Value.	Error.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
Interpolated precipitation at Dannemora, N. Y., from Chazy, Harkness, and Moria records, 1906–1915.																									
Jan., 1907	1.26	2.16	0.90	1.81	0.55	1.63	0.37	1.59	0.33	1.25	−0.01	1.47	0.21	1.30	0.04	1.58	0.32	1.79	0.53	1.83	0.57	1.77	0.51	1.76	0.50
Feb., 1910	3.88	2.15	−1.73	1.51	−2.37	2.74	−1.14	1.49	−2.39	2.20	−1.68	3.25	−.63	2.90	−.88	3.49	−.39	4.00	.12	3.62	−.26	5.40	1.62	5.44	1.56
Mar., 1909	2.30	2.20	−.10	2.95	.65	3.75	1.45	2.92	.62	.98	−1.32	1.63	−.67	1.50	−.80	1.77	−.53	2.07	−.23	1.83	−.47	1.62	−.68	1.59	−.71
Apr., 1911	0.74	2.28	1.54	2.74	2.00	2.28	1.54	2.69	1.95	.33	−.41	0.66	−.12	.54	−.20	.68	−.06	.74	0	.91	.17	.88	.14	.86	.12
May, 1913	2.24	3.46	1.22	2.32	.08	3.08	.84	3.16	.92	2.36	.12	2.35	.11	2.72	.48	2.63	.39	3.75	1.31	2.76	.52	4.06	1.72	4.11	1.87
June, 1912	1.42	2.80	1.38	4.50	3.18	2.95	1.53	5.45	4.03	1.50	.08	1.25	−.17	.90	−.42	1.36	−.06	1.24	−.18	1.37	−.05	.95	−.47	.92	−.50
July, 1910	3.04	3.17	.13	2.56	−.48	2.87	−.17	2.92	−.12	1.95	−1.09	2.87	−.17	2.70	−.34	1.14	−1.90	3.72	.68	3.11	.07	2.46	−.58	2.48	−.56
Aug., 1912	4.58	2.74	−1.84	4.58	0	2.28	−2.30	3.84	−.74	4.69	.11	3.92	−.66	4.05	−.53	4.49	−.09	5.58	1.00	3.81	−.77	3.63	−.95	3.78	−.80
Sept., 1907	6.93	3.37	−3.56	1.33	−5.60	2.03	−4.90	3.39	−3.54	6.50	−.43	6.04	−.89	6.27	−.66	6.92	−.01	8.65	1.72	7.05	.12	4.66	−2.27	4.69	−2.24
Oct., 1908	1.66	2.53	.87	1.42	−.24	1.45	−.21	1.38	−.28	.93	−.73	1.29	−.37	1.20	−.46	1.41	−.25	1.65	−.01	1.39	−.27	1.62	−.04	1.59	−.07
Nov., 1913	2.36	1.83	.53	3.42	1.06	2.88	.52	2.36	0	.22	−2.14	1.38	−.98	1.06	−1.30	1.38	−.98	1.46	−.90	1.17	−1.19	2.44	.08	2.38	.02
Dec., 1914	2.14	2.74	.60	2.00	−.14	2.76	.62	2.74	.60	.80	−1.34	1.95	−.19	1.60	−.54	2.00	−.14	2.20	.06	2.44	.30	2.10	−.04	2.11	−.03
Year	32.55	31.43	−1.12	32.46	−.09	30.72	−1.83	33.93	+1.38	23.71	−8.84	28.06	−4.49	26.74	−5.81	28.85	−3.70	36.85	+1.30	31.29	−1.26	31.59	+0.96	31.71	−.84
Mean			1.20		1.36		1.30		1.30		.79		.43		.55		.43		.56		.40		.76		.75
Interpolated precipitation at T. S. Ranch, Mesa Co., Colo., from Cedar Edge, Collbran and Grand Junction, 1892–1901.																									
Jan., 1899	0.29	0.68	0.39	0.42	0.13	0.38	0.09	0.39	0.10	0.42	0.13	0.54	0.25	0.39	0.10	0.52	0.23	0.43	0.14	0.45	0.16	0.44	0.15	0.38	0.09
Feb., 1893	1.01	0.73	−.28	.70	−.31	.92	−.09	.59	−.42	1.77	.76	2.69	1.68	2.11	1.10	2.54	1.53	2.34	1.33	1.80	.79	2.37	1.36	2.54	1.53
Mar., 1897	1.88	1.14	−.74	1.30	−.58	.68	−1.20	1.87	−.01	1.05	−.83	1.48	−.40	1.43	−.45	1.44	−.44	1.59	−.29	1.40	−.48	1.55	−.33	1.39	−.49
Apr., 1899	1.56	.84	−.72	.88	−.68	1.17	−.39	1.01	−.55	1.11	−.45	.79	−.77	.93	−.63	.83	−.73	1.03	−.53	.65	−.91	1.99	.43	1.72	.16
May, 1894	0.75	.79	.04	.37	−.38	.48	−.37	.43	−.32	.56	−.19	.59	−.16	.61	−.14	.60	−.15	.68	−.07	.50	− 25	1.63	.88	1.34	.59
June, 1898	0.15	.54	.39	1.34	1.19	1.20	1.15	.87	.72	.05	−.10	.28	.13	.13	−.02	.22	.07	.14	−.01	.19	.04	.17	.02	0.20	.05
July, 1895	1.73	.86	−.87	1.10	−.63	1.02	−.71	1.04	−.69	1.43	−.30	1.41	−.32	1.38	−.35	1.41	−.32	1.53	−.20	1.51	−.22	1.10	−.63	1.14	−.59
Aug., 1896	0.45	1.27	.82	3.00	2.55	1.17	.72	3.81	3.36	1.01	.56	1.10	.65	1.00	.55	1.08	.63	1.11	.66	1.34	.89	1.44	.99	1.39	.94
Sept., 1900	0.80	1.14	.34	.50	−.30	.34	−.46	.44	−.36	1.18	.38	1.50	.70	1.58	.78	1.51	.71	1.75	.95	1.51	.71	3.35	2.55	2.38	1.58
Oct., 1900	0.87	1.30	.53	.84	−.03	.05	−.82	1.33	.46	.14	−.73	.84	−.03	.87	0	.75	−.12	.97	.10	.98	.11	.31	−.56	.45	−.42
Nov., 1897	0.86	.50	−.36	1.21	.35	.40	−.26	.61	−.25	.33	−.53	1.65	.79	.58	−.28	.59	−.27	.64	−.22	.47	−.39	.39	−.47	.44	−.42
Dec., 1893	1.20	.72	−.48	.48	−.72	.96	−.24	.61	−.59	.50	−.70	1.28	.08	.76	−.54	1.15	−.05	.84	−.36	1.07	−.13	.52	−.68	.61	−.59
Year	11.55	10.52	−1.03	12.14	+0.59	9.44	−2.11	13.00	1.45	9.55	−2.00	14.13	2.58	11.77	+.22	12.64	1.09	13.05	1.50	11.87	+.32	15.26	3.71	13.98	+2.43
Mean			.50		.65		.54		.65		.47		.50		.41		.44		.41		.42		.75		.62
Interpolated precipitation at New Iberia, La., from Franklin, Lafayette, and Abbeville records, 1900–1909.																									
Jan., 1908	4.05	3.60	−0.45	3.36	−0.69	2.45	−1.60	5.14	1.09	[a] 3.29	−0.76	3.59	−0.46	3.60	−0.45	3.65	−0.40	3.44	−0.61	3.83	−0.22	2.96	−1.09	2.90	−1.15
Feb., 1901	6.05	4.91	−1.14	5.29	−0.76	5.40	−.65	4.81	−1.24	4.50	−1.55	5.10	−.95	5.50	−.55	5.48	−.57	5.26	−.79	4.76	−1.89	8.66	2.61	7.93	1.18
Mar., 1909	.80	3.84	3.04	3.86	3.06	1.82	−1.02	4.56	3.76	0.59	−.21	.61	−.19	.60	−.20	.62	−.18	.57	−.23	.60	−.20	.77	−.03	.74	−.06
Apr., 1902	4.30	4.95	0.65	4.35	.05	5.80	1.50	2.87	−1.43	3.51	−.79	4.19	−.11	4.05	−.25	3.88	−.42	3.87	−.43	4.47	.17	4.87	.57	4.89	.59
May, 1906	2.22	4.78	2.56	3.45	1.23	10.98	8.76	2.34	.12	1.45	−.77	1.88	−.34	2.30	−.08	1.87	−.35	2.20	−.02	1.71	−.41	2.48	.26	2.19	−.03
June, 1903	5.70	5.47	−0.23	3.65	−2.05	2.18	−3.52	5.44	−.26	4.22	−1.48	3.93	−1.77	4.05	−1.65	3.97	−1.73	3.87	−1.83	4.27	−1.43	5.95	.25	4.70	−1.00
July, 1905	10.58	9.33	−1.25	10.60	.02	10.60	.02	8.46	−2.42	8.67	−1.87	9.16	−1.42	9.70	−.88	9.24	−1.34	9.27	−1.31	8.25	−2.33	9.96	−.62	9.25	−1.33
Aug., 1904	3.90	6.71	2.81	8.15	4.25	5.22	1.32	10.75	6.85	7.37	3.47	6.94	3.04	6.80	2.90	7.08	3.18	6.50	2.60	7.20	3.30	7.99	4.09	8.10	4.20
Sept., 1902	4.50	5.47	0.97	5.10	.60	4.50	0	3.98	−.52	3.36	−1.14	4.70	.20	4.15	−.35	4.73	.23	3.97	−.53	4.50	0	6.64	2.14	6.24	1.74
Oct., 1908	1.25	2.58	1.33	3.88	2.43	4.25	3.00	4.46	3.21	0.40	−.85	.49	−.76	.50	−.75	.50	−.75	.48	−.77	.46	−.79	.23	−1.22	.55	−.70
Nov., 1905	6.45	2.40	−4.05	3.58	−2.87	.92	−5.53	3.30	−3.15	6.14	−.31	3.42	−3.03	5.00	−1.45	3.47	−2.98	4.78	−1.67	4.75	−1.70	4.77	−1.68	5.26	−1.19
Dec., 1907	4.51	4.48	−.03	4.28	−.23	2.50	−2.01	3.34	−1.17	6.12	1.61	5.17	.66	4.10	−.41	5.27	.76	3.92	−.59	5.16	.65	4.75	.24	4.70	.19
Year	54.31	58.54	+4.23	59.55	+5.24	56.62	2.31	59.15	4.84	49.62	−4.69	49.18	−5.13	50.35	−3.96	49.76	−4.55	50.70	−3.61	49.96	−4.35	60.03	+5.72	57.45	+3.14
Mean			1.54		1.52		2.41		2.10		1.24		1.08		.83		1.07		.95		1.09		1.22		1.11
Interpolated precipitation at North Bloomfield, Calif., from Bowman's Dam, Blue Canyon, and Nevada City records, 1899–1908.																									
Jan., 1904	3.85	11.38	7.53	10.12	6.27	9.60	5.75	12.52	8.67	[b] 5.37	1.52	4.31	+0.46	4.60	0.75	3.58	−0.27	3.69	−0.16	3.47	−0.38	2.23	−1.62	2.41	−1.44
Feb., 1905	7.05	10.07	3.02	9.72	2.67	13.19	6.14	8.16	−1.11	8.97	1.92	7.76	.71	8.35	1.30	6.60	−.45	6.70	−.35	6.10	−.95	6.70	−.35	6.77	−.28
Mar., 1903	15.04	12.68	−2.36	2.36	-12.68	14.15	−.89	4.37	-10.67	17.32	2.28	15.07	.03	16.00	.96	8.53	−6.51	12.85	−2.19	12.41	−2.63	10.52	−4.52	10.94	−4.10
Apr., 1901	5.29	3.61	−1.68	4.05	−1.24	4.09	−1.20	1.88	−3.41	5.99	.70	5.27	−.02	5.35	−.06	3.83	−1.46	4.30	−.99	4.48	−.81	9.96	4.67	9.22	3.93
May, 1902	1.70	2.88	1.18	2.79	1.09	1.16	−.54	3.18	1.48	2.76	1.06	2.16	.46	1.50	−.20	1.80	.10	1.20	−.50	1.68	−.02	2.17	.47	2.11	.41
June, 1905	0.22	1.29	1.07	2.10	1.88	2.16	+1.94	1.80	1.58	1.72	1.50	.79	.57	1.30	1.08	.60	.38	1.04	.82	.56	.34	.69	.47	.61	.39
July, 1905	0	0.12	.12	2.11	2.11	0	0	.04	.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug., 1901	T.	.83	.83	2.29	2.29	.02	.02	.27	.27	.05	.05	.01	.01	.05	.05	.01	.01	.04	.04	T.	0	.69	.69	.03	.03
Sept., 1907	0.15	1.29	1.14	.48	.33	.31	.16	.23	.08	.17	.02	.07	−.08	.20	.05	.42	.27	.16	.01	.07	−.08	.06	−.09	.05	−.10
Oct., 1906	0.14	4.50	4.36	1.98	1.84	.56	.42	2.30	2.16	.79	.65	.48	.35	.60	.46	.38	.24	.48	.34	.82	.68	.40	.26	.40	.26
Nov., 1902	6.09	6.50	.41	6.24	.15	9.98	3.89	5.52	−.57	10.04	3.95	8.03	1.94	8.75	2.66	6.71	.62	7.03	.94	6.97	.88	6.61	.52	6.58	.49
Dec., 1903	3.80	8.23	4.43	4.56	.76	8.02	4.22	3.83	.03	6.19	2.39	4.19	.39	5.05	1.25	3.52	−.27	4.05	.25	3.54	−.26	1.64	−2.16	1.50	−2.30
Year	43.33	63.38	20.05	48.80	+5.47	63.24	19.91	44.10	+0.77	59.37	+16.04	48.15	+4.82	51.75	+8.42	35.99	−7.34	41.54	−1.79	40.10	−3.23	41.67	−1.66	40.62	−2.71
Mean			2.34		2.78		2.20		2.51		1.38		.42		.74		.89		.55		.59		1.33		1.14

[a] Abbeville record

[b] Bowman Dam record.

TABLE 2.—*Comparison of methods of interpolating missing monthly rainfall records.*

Method of interpolation.	Dannemora, N. Y.	New Iberia, La.	T. S. Ranch, Colo.	North Bloomfield, Calif.	Average for the four stations.
(1)	(2)	(3)	(4)	(5)	(6)
Annual precipitation=total of the 12 months used	32.55	54.31	11.55	43.33	35.44
Average monthly precipitation	2.71	4.52	.96	3.61	2.95
Average error per month in inches.					
1-*a*. Normal	1.20	1.54	.50	2.34	1.40
1-*b*. Average of preceding and following months	1.36	1.52	.65	2.78	1.58
1-*c*. Average same month preceding and following years	1.30	2.41	.54	2.20	1.61
1-*d*. Angot method	1.30	2.10	.65	2.51	1.64
2-*a*. Nearest station	.79	1.24	.47	1.38	.97
2-*b*. Average of three surrounding stations	.43	1.08	.50	.42	.61
2-*c*. Inclined plane method	.55	.83	.41	.74	.63
3-*a*. Fournie method	.43	1.07	.44	.89	.71
3-*b*. Fournie-Horton method	.56	.95	.41	.55	.62
3-*c*. Abnormality method	.40	1.09	.42	.59	.63
3-*e*. Angot-Horton method	.76	1.22	.75	1.33	1.02
3-*f*. Angot-Leach ratio	.75	1.11	.62	1.14	.90
Mean	.78	1.35	.53	1.41	1.02
Average algebraic error.[a]					
1-*a*. Normal	0.09	0.35	0.09	1.67	0.55
1-*b*. Average of preceding and following months	.01	.44	.05	.46	.24
1-*c*. Average same month preceding and following years	.15	.19	.18	1.66	.54
1-*d*. Angot method	.12	.40	.12	.06	.18
2-*a*. Nearest station	.74	.39	.17	1.34	.66
2-*b*. Average of three surrounding stations	.37	.43	.22	.40	.36
2-*c*. Inclined plane method	.48	.33	.01	.70	.38
3-*a*. Fournie method	.31	.38	.09	.61	.35
3-*b*. Fournie-Horton method	.11	.30	.13	.15	.17
3-*c*. Abnormality method	.10	.36	.03	.27	.19
3-*e*. Angot-Horton method	.08	.48	.31	.14	.25
3-*f*. Angot-Leach ratio	.07	.28	.20	.23	.19
Mean	.22	.36	.13	.66	.34

[a] One-twelfth of the annual or total algebraic error.

The more refined methods, combining the data for the base and interpolation stations and including correction for local variation, give the most accurate results, especially with reference to reduction of the constant errors. Since the accuracy of interpolation varies with the amount and variability of the rainfall, the relative errors differ for the different stations, as shown in Table 4, which gives the average of all of the arithmetic and algebraic errors of 144 interpolations for each of the four interpolation stations.

Since all the different methods are not readily carried in mind, a brief statement of each, together with an estimate of the comparative labor involved in its use and the comparative accuracy of the results is given in Table 5. The comparative labor involved is estimated approximately on the basis of the time in minutes required to make a single interpolation when all the data, including normals, if any are required, have been compiled and are directly available.

In comparing the merits of different interpolation methods, three things are to be considered:

1. Labor involved.
2. Arithmetic error of individual interpolated values.
3. Total or average algebraic error of interpolated values. For a single or limited number of interpolations, simplicity and relative accuracy of the individual interpolations are most important. Where many interpolations are to be made, the constant coefficient methods, Fournie's, the abnormality, and the correction ratio methods become relatively much less laborious than where they are used for a small number of interpolations, since the coefficients or weights when once computed for a given group of stations can be used for all interpolations involving the same stations.

TABLE 3.—*Summary of rainfall interpolation methods—average results by different methods for all four groups of stations.*

Method.	Average monthly error.		Total average algebraic error.	
	Inches per month.	Per cent of true value.	Inches per month.	Per cent of average month precipitation.
(1)	(2)	(3)	(4)	(5)
Methods using same station only.				
1-*a*. Normal	1.40	62.7	±0.55	18.7
1-*b*. Preceding and following month	1.58	140.6	.24	8.1
1-*c*. Same month preceding and following years	1.61	108	.55	18.7
1-*d*. Angot method	1.64	92	.18	6.1
Average	1.56	100.8	.38	12.9
Contemporary record methods.				
2-*a*. Nearest station	.97	67.7	.66	22.4
2-*b*. Average of three surrounding stations	.61	43.8	.35	11.9
2-*c*. Inclined plane	.63	47.7	.38	12.9
Average	.74	53.1	.46	15.7
Combined methods.				
3-*a*. Fournie	.71	40.8	.35	11.9
3-*b*. Fournie-Horton	.62	41.2	.17	5.8
3-*c*. Abnormality	.63	40.4	.19	6.4
3-*e*. Angot-Horton method	1.02	50.4	.25	8.5
3-*f*. Angot-Leach ratio	.90	47.6	.19	6.4
Average	.78	44.1	.23	7.8

Average annual precipitation of the four stations 35.44
Average monthly precipitation of the four stations 2.95

Column 2=Average monthly error in inches. (Column 6, Table 2.)

Column 3=Average of the individual errors in per cent. Percentage for each month=error/true value.

Column 4=Average algebraic error=average annual error/12.

Column 5=Column 4 expressed as percentage of average monthly rainfall at all stations=column 4/2.95.

TABLE 4.—*Average results of all methods of rainfall interpolation methods at each of the four stations used.*

Station.	Average monthly precipitation.[a]	Average arithmetic error.		Average of the algebraic errors.	
		Inches per month.	Per cent per month.	Inches per month.	Per cent per month.
(1)	(2)	(3)	(4)	(5)	(6)
Dannemora, N. Y.	2.71	0.78	34.2	±0.22	8.1
New Iberia, La.	4.52	1.35	43.6	.36	8.0
T. S. Ranch, Colo.	.96	.53	77.9	.13	13.5
North Bloomfield, Calif.	3.61	1.41	105.2	.66	18.3

[a] Average of the 12 months used.

Column 3=Arithmetic average of the individual errors disregarding sign.

Column 4=Average of the individual per cent errors.

Column 5=Arithmetic average of one-twelfth of the annual algebraic error for each method.

Column 6=Column 5 expressed as per cent of average monthly precipitation, column 2.

TABLE 5.—*Summary of monthly rainfall interpolation methods.*

Group and method.	Description.	Other stations required.	Normals required.	Constant error.	Relative labor.[a] Few cases.	Relative labor.[a] Many Cases.	Average monthly error, per cent. Arithmetic.	Average monthly error, per cent. Algebraic.	Sum of (8) and (9).
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1-a	Normal: Substitution of mean for same month	No.	1	No.	1	1	62.7	18.7	81
1-b	Use of mean of preceding and following months	No.	No.	Yes.	3	3	140.6	8.1	149
1-c	Mean of same month preceding and following years	No.	No.	Yes.	3	3	108	18.7	127
1-d	Angot method: Normals used with means of preceding and following months. $d=\frac{D}{D_1+D_2}\times\frac{d_1+d_2}{2}$	No.	3	No.	8	4	92	6.1	98
2-a	Use of nearest station record for same month	No.	No.	Yes.	1	1	67.7	22.4	90
2-b	Average of three surrounding stations: $d=\frac{a+b+c}{3}$	3	No.	Yes.	3	3	43.8	11.9	60
2-c	Inclined plane, with three surrounding stations	3	No.	Yes.	10	10	47.7	12.9	61
3-a	Fournie method: $d=\frac{1}{3}\left(\frac{D}{A}a+\frac{D}{B}b+\frac{D}{C}c\right)$	3	4	No.	20	10	40.8	11.9	53
3-b	Fournie-Horton: A ratio deduced from the three Fournie values $\frac{D}{A}$, $\frac{D}{B}$, $\frac{D}{C}$ by the inclined plane method is applied to the value of d deduced directly by the inclined plane method	3	4	No.	40	20	41.2	5.8	47
3-c	Abnormality method: $d=\frac{1}{3}\left(\frac{a}{A}D+\frac{b}{B}D+\frac{c}{C}D\right)$. Identical with Fournie method, but computed differently	3	4	No.	20	10	40.4	6.4	47
3-d	Correction-Ratio method: Uses contemporary data for three surrounding stations. $d=\frac{1}{3}\left(\frac{a}{a_1+a_2}+\frac{b}{b_2+b_2}+\frac{c}{c_1+c_2}\right)(d_1+d_2)$	3	No.	No.	20	20	(b)	(b)	....
3-e	Horton method: Same as preceding, but correction factor applied to d_1+d_2 obtained by applying inclined plane method to the three ratios	3	No.	No.	30	30	50.4	8.5	59
3-f	Leach method: Same as preceding, except that the three ratios are weighted by inverse distances from base station	3	No.	No.	30	20	47.6	6.4	54

Notation A, B, C, D, normals at base and interpolation stations, respectively; a, b, c, d, monthly and interpolated values, subscripts 1 and 2 relate to preceding and following months.

[a] In estimating relative labor, it is assumed that normals and other data are directly available without computation.

[b] Not determined.

Independent of the labor involved, the value of a method may be considered as about proportional to the sum of the average and algebraic errors resulting from its use. This sum is shown in column (10) of Table No. 5. Where many interpolations are required it becomes important that the total or algebraic mean error of all interpolations should be small or that the algebraic errors should tend to vanish as the number of interpolated values increases. In the case of certain methods the algebraic error may be cumulative, there being a constant difference involved between the interpolated and true values. This may result in using (*a*), the nearest station; (*b*), the mean of three surrounding stations; (*c*), the mean of the preceding and following months. Where the interpolation months are scattered equally throughout the year there should be no tendency for a cumulative algebraic error in using the last-named method. For stations having relatively small precipitation, as, for example, North Bloomfield, Calif., the percentages of errors are misleading. A percentage of error of even 1,000 per cent for a month with a precipitation of only 0.01 inch may be of little importance hydrologically, whereas a 10 per cent error for a monthly precipitation of 10 inches would be of much greater significance. On the other hand, actual errors taken alone may be misleading, since actual errors in inches are likely to be smaller with stations for small than for stations with large precipitation.

The simplest methods, Groups 1 and 2, involve relatively little labor, but the errors are comparatively large. As regards accuracy, the mean of three surrounding stations and the inclined plane method are decidedly the best in these groups. As between the direct use of the average of three surrounding stations and the application of the inclined plane method, the results given in the table show little choice. It appears certain, however, that inasmuch as the inclined plane method gives weights to the surrounding stations, decreasing as their distances from the interpolation station increase, this method if applied to a sufficient number of cases to give a decisive result would show greater accuracy than the simple average for three surrounding stations. While the labor involved in the use of the inclined plane method is somewhat greater than where the simple average of three stations is used, yet it is comparatively slight in any event, and the use of the inclined plane method in preference to the simple average of three stations seems advisable.

With reference to the methods of Group No. 3, the differences in accuracy are not very large. All methods of Group 3 show materially smaller algebraic errors than the simpler methods. The choice between the methods of Group 3 must apparently, therefore, depend largely on the labor involved. There is no very great difference between the methods of Group 3 when the data have once been compiled. In the case of methods involving the use of normals, viz., Fournie, Fournie-Horton, and Angot methods, the actual labor for a small number of interpolations will often be much greater than the relative labor indicated by the table, especially if the normals themselves are not available without computation. If, therefore, results substantially as accurate as those obtained by the use of methods involving normals can be procured without the use of normals, then the methods avoiding the use of normals are generally to be preferred. The Horton and Leach methods do not involve the use of normals but are based entirely on contemporaneous records. They take into account the relative positions of the stations and utilize data for the base as well as for surrounding stations, and as shown by Table 5, the accuracy of these methods is nearly equal to that obtained by the use of methods involving normals. As between the Horton and Leach methods, the advantage appears to lie generally with the latter, both in point of accuracy and in simplicity of application, especially where many interpolations are made, since the ratios once de-

termined for the Leach method for a given month and group of stations can be applied to other interpolations at the same station for the same month of the year. If two of the base stations happen to lie nearly in line with the interpolation station, then the inclined plane method gives comparatively little weight to the third base station. Under such conditions the method of weighting by inverse distances, used in the Leach method, is preferable. Inasmuch as the studies thus far made indicate that

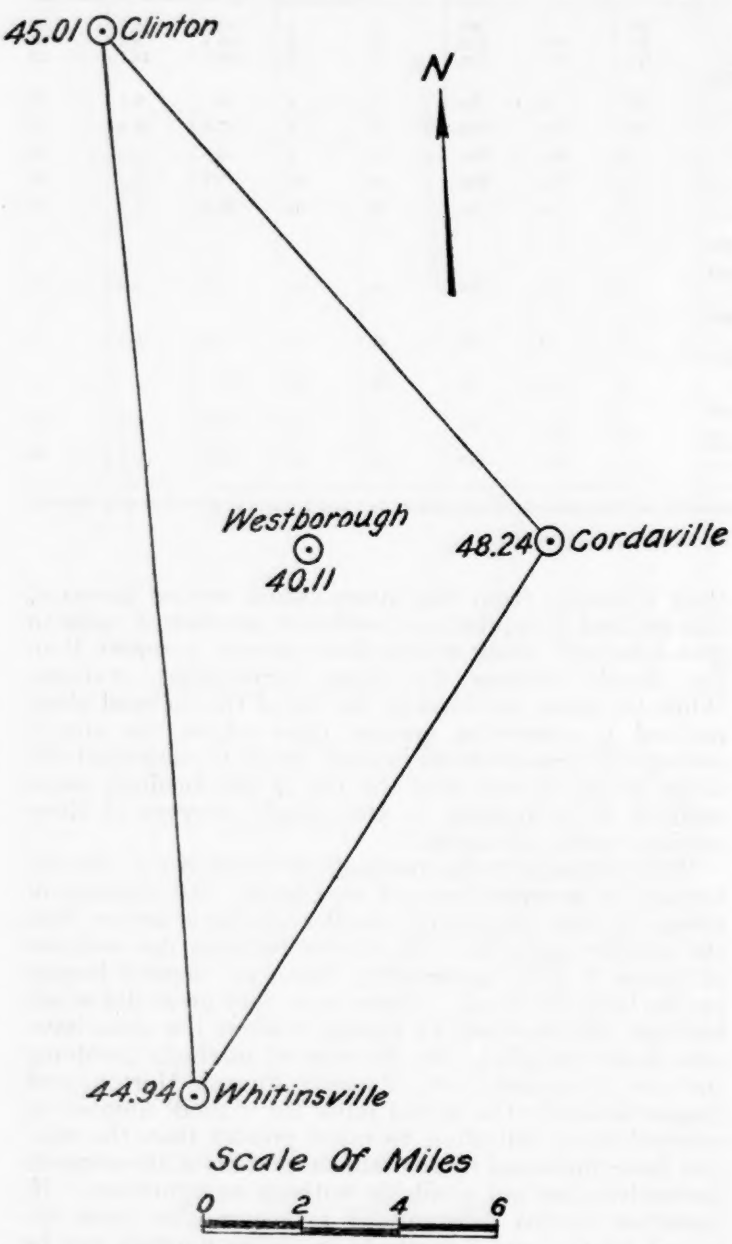

Fig. 7.—Location of rainfall stations, Massachusetts group. (Figure gives mean annual rainfall.) 1895-1908, inclusive.

nearly as great accuracy can be obtained by the use of the Horton and Leach methods without the use of normals as from those methods involving normals. A further study was made to test the applicability of these two methods to localities of moderately variable rainfall. Groups of stations were chosen in Massachusetts, Michigan, and Nebraska, Figures 7, 8, and 9. Interpolations first were made for a total of 10 months for each station by using the mean of three surrounding stations. The results are given in the first line of each section of Table No. 6.

Table 6.—*Comparison of methods 2–b, 3–e, and 3–f for the interpolation of rainfall records.*

	Method.	West-boro, Mass.	Battle Creek, Mich.	Ashton, Nebr.	Mean.
Actual precipitation 10 months (inches)	....	31.57	32.63	20.30	....
Total of 10 monthly interpolations (inches)	2–b	32.70	32.62	19.74	....
	3–e	30.61	42.32	22.63	....
	3–f	31.41	38.48	20.23	....
Algebraic error of 10 monthly interpolations inches	2–b	1.19	–.01	–.56	0.21
	3–e	–.90	9.69	2.33	3.71
	3–f	–.10	5.86	–.07	1.90
Arithmetic average monthly error of interpolation (inches)	2–b	.407	.627	.51	.51
	3–e	.456	1.615	.623	.90
	3–f	.424	1.465	.435	.77
Average monthly percentage of error of interpolation	2–b	15.7	29.7	77.8	41.1
	3–d, e	15.3	63.6	51.7	43.5
	3–e, f	14.5	57.0	45.8	39.1
Number of plus errors	2–b	6	5	6	....
	3–e	5	7	7	....
	3–f	5	6	7	....
Number of minus errors	2–b	4	5	3	....
	3–e	5	3	2	....
	3–f	5	4	2	....

2–b= Average of the three nearest stations.
3–e= Corrected ratio to the preceding and following months.
3–f= Weighted (inversely as distance) corrected ratio to preceding and following months.

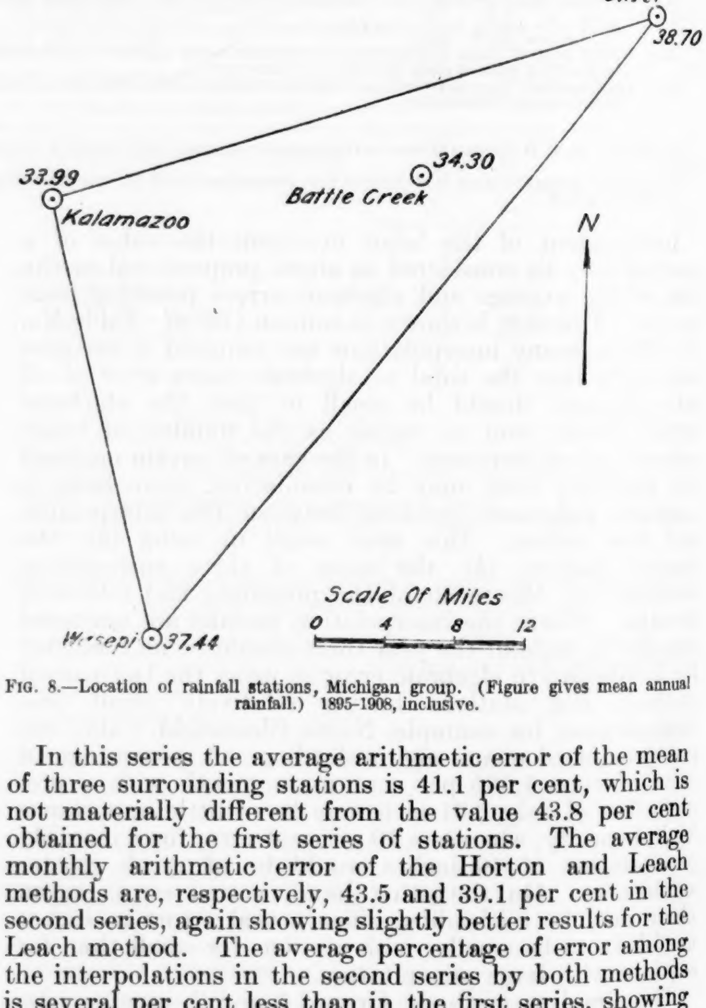

Fig. 8.—Location of rainfall stations, Michigan group. (Figure gives mean annual rainfall.) 1895-1908, inclusive.

In this series the average arithmetic error of the mean of three surrounding stations is 41.1 per cent, which is not materially different from the value 43.8 per cent obtained for the first series of stations. The average monthly arithmetic error of the Horton and Leach methods are, respectively, 43.5 and 39.1 per cent in the second series, again showing slightly better results for the Leach method. The average percentage of error among the interpolations in the second series by both methods is several per cent less than in the first series, showing that better results are obtained by these methods in regions of moderate than in regions of high rainfall variability. It will be noted that in the second series the Horton and Leach methods do not give quite as small an average monthly percentage of error as is obtained from the direct average of three surrounding stations. The same was true in the first series. Again, the Horton and Leach method give larger algebraic monthly errors in the second series than does the simple

average of three surrounding stations. This, however, apparently results almost entirely from an accidentally small error of the average of three surrounding stations for the interpolations at Battle Creek, and in the first series the average monthly algebraic error of the Horton and Leach methods was materially less than for interpolations based on the direct average of three surrounding stations.

While the number of sample compilations compared in these studies is obviously insufficient for a final determination of the relative accuracy of different methods, yet the following tentative conclusions appear to be justified. In this connection it should be borne in mind that the arithmetic error indicates the probable departure of a single interpolated value from the true value. The algebraic error shows the tendency for

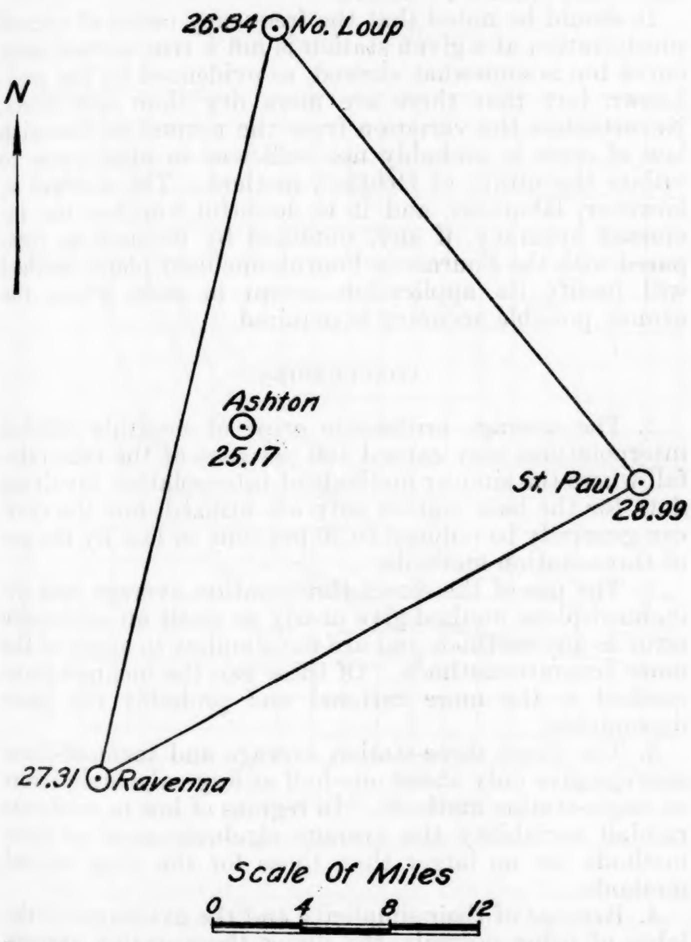

FIG. 9.—Location of rainfall stations, Nebraska group. (Figure gives mean annual rainfall.) 1895–1908, inclusive.

the occurrence of set or cumulative errors. If the monthly errors tend to counterbalance, the algebraic error will be small. The sum of the two errors here used as an utility index has no statistical meaning, except that if it is large at least one of the errors is necessarily large.

INTERPOLATION OF ANNUAL RAINFALL AND REDUCTION TO BASE PERIOD.

The preceding discussion has been devoted to interpolation of missing monthly rainfall amounts. The same methods can of course be applied to filling in missing seasonal or annual values. In general, since annual is less variable than monthly rainfall, the accuracy of the result will be greater for annual than for monthly rainfall. It is important in preparing maps of average rainfall or in determining the mean rainfall on a drainage basin to reduce all the records used to a uniform base period. If some of the records available do not cover the entire base period a suitable method should be used to reduce these records so as to obtain the approximate average rainfall at the same stations for the base period. The simplest procedure is the use of the direct ratio method, often used in Europe and attributed to Hugo Meyer[5] in which the derived average is

$$P' = \frac{P}{a} X A = \frac{A}{a} X P \qquad (1)$$

where A is the base period average at an adjacent station, a is the average at the same station for the period covered by records at both the base and interpolation stations, P is the mean precipitation at the interpolation station for the period of record. It will be seen that this is identical with the Fournie method already described, except that in the latter, three base stations are used. Designating the other two stations B and C, and using notation similar to above, the average precipitation for the base period at the interpolation station is obtained by the formula,

$$P' = \frac{P}{3}\left(\frac{A}{a} + \frac{B}{b} + \frac{C}{c}\right) \qquad (2)$$

This is an excellent method of reduction to a base period and is the one most generally used in the United States. It is more rational and probably more accurate in most cases to apply the inclined plane method to the ratios $\frac{A}{a}$, $\frac{B}{b}$ and $\frac{C}{c}$. Then, calling the resultant ratio for the location of the interpolation station r', the resulting base period average for the interpolation station is,

$$P' = r' P \qquad (3)$$

Recently Von P. Heidke[6] described a method of extension of short rainfall records based on the method of least squares. Several stations are used as in the Fournie method. They are given weights inversely proportional to the squares of the mean errors of the reduced means for the individual stations. First, trial values of the rainfall P' for the interpolation station are computed by the use of Meyer's ratio for each base station. Calling these trial values P'_a, P'_b, P'_c, etc., and the weights to be applied to them w_a, w_b, w_c, etc., the base period precipitation at the interpolation station is obtained by means of the formula,

$$P' = \frac{w_a P'_a + w_b P'_b + w_c P'_c + \text{etc.}}{w_a + w_b + w_c + \text{etc.}} \qquad (4)$$

The true mean errors of the reduced means derived from the several base stations can not of course be determined in advance, since the true base period precipitation at the interpolation station is unknown. Heidke, however, assumes that the true mean errors for the several base stations are proportional to the corresponding mean errors of the precipitation amounts P'_a, P'_b, P'_c, etc., derived by the use of the Meyer ratios for the several base stations. Calling these mean errors m_a, m_b, etc.,

[5] Anleitung zur Bearbeitung meteorologischer Beobachtungen für die Klimatologie, Berlin, 1891.

[6] Reduktion kürzerer Reihen von Niederschlagsmessungen auf die langjährigan homogener Nachbarstationen unter Berücksichtigung von Gewichten,— *Meteorologische Zeitschrift*, June, 1923, pp. 167–173.

the corresponding weights to be applied in formula (4) are,

$$w_a = \frac{c}{m_a^2},\ w_b = \frac{c}{m_b^2},\ \text{etc.} \tag{5}$$

where c either equals unity or may be given an arbitrary value, say 100, more convenient for computation purposes.

The following table (7) illustrates the method of computation of the weight w for Rehoboth to be used in determining the long term average precipitation from a short record at Mariental. Column (2) shows the available precipitation date at Mariental and column (3) shows the corresponding precipitation at Rehoboth. The ratio of the means, including two incomplete record years, is 0.753. Using this value of the Meyer ratio the trial values of precipitation at Mariental for the same years are computed as shown in column (6). The departures of these trial values from the true values are next determined, as shown in column (7), and their squares taken, as given in column (8). The mean error of the trial values is determined by the formula,

$$m = \sqrt{\frac{\Sigma(\Delta^2)}{n}} \tag{6}$$

where n is the number of years of complete record, which is nine in this case. This leads to a value 0.12 for the weight to be applied to Rehoboth base station. Proceeding in a similar manner weights to be applied to other base stations are determined.

TABLE 7.—*Computation of weight, Heidke's method.*

Year.	Precipitation		$P/a = \frac{(2)}{(3)}$	Departure of (2) from mean= (2)−146.	0.753 ×(3).	(2)−(6)	(7)²
	Mariental =*P*.	Rehoboth =*a*.					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mm.	*Mm.*		*Mm.*	*Mm.*	*Cen.*	*Cen.*
1899-1900	[a] 189	193	....	....	145	4	....
1900-1901	102	167	0.61	−44	126	−2	4
1901-02	86	123	0.70	−60	93	−1	1
1902-03	132	111	1.19	−14	84	5	25
1903-04	286	398	0.72	140	300	−1	1
1907-08	[a] 177	199	....	....	150	3	....
1908-09	234	343	0.68	88	258	−2	4
1909-10	172	257	0.67	26	194	−2	4
1910-11	56	106	0.53	−90	80	−2	4
1911-12	152	262	0.58	6	197	−4	16
1912-13	97	76	1.28	−49	57	4	16
Σ	1,683	2,235	....	....	1,684	+16	75
Average	[b] 146	[b] 205	0.77	57.4	....	−14	....

$$\text{Ratio of means} = \frac{1{,}683}{2{,}235} = 0.753 = r_1$$

$$m = \sqrt{\frac{\Sigma(\Delta^2)}{n}} = \sqrt{\frac{75}{9}} = 29 \text{ cen.} = 290 \text{ mm.}$$

$$w = \frac{100}{29^2} = 0.12$$

[a] Incomplete year, interpolated.
[b] Average for nine complete years.

This method involves two assumptions:

(1) That the departures of individual rainfall amounts from the average behave as normal errors.

(2) That the true mean errors of the rainfall at the interpolation station are porportional to the trial mean errors determined from Meyer's ratios.

To test the first assumption, Heidke uses the criterion that for normal errors.

$$\frac{2n\,[\Sigma\,\Delta^2]}{\Sigma \pm \Delta} = \pi$$

Calling E_1 the true value of the left-hand member of equation (6), derived from two simultaneous long-term records, and calling E_2 the approximate value derived from the use of Meyer ratios, Heidke obtains by a comparison of five pairs of stations having 50-year records, average values of E_1 and E_2 as follows: $E_1 = 3.07$, $E_2 = 3.21$. Similarly, from a comparison of 30-year records for five pairs of stations he obtains: $E_1 = 2.96$, $E_2 = 3.15$. From five pairs of 20-year records he obtains: $E_1 = 2.86$, $E_2 = 3.09$. These are to be compared with the theoretical value, $\pi = 3.1416$.

It should be noted that the frequency curve of annual precipitation at a given station is not a true normal error curve but is somewhat skewed, as evidenced by the well-known fact that there are more dry than wet years. Nevertheless the variation from the normal or Gaussian law of error is probably not sufficient in most cases to vitiate the utility of Heidke's method. The method is, however, laborious, and it is doubtful whether the increased accuracy, if any, obtained by its uses as compared with the Fournie or Fournie-inclined plane method will justify its application except in cases where the utmost possible accuracy is required.

CONCLUSIONS.

1. The average arithmetic error of monthly rainfall interpolations may exceed 100 per cent of the true rainfall where the simpler methods of interpolation involving data for the base station only are utilized, but the error can generally be reduced to 50 per cent or less by the use of three-station methods.

2. The use of the direct three-station average and the inclined-plane method give nearly as small an arithmetic error as any methods and are the simplest to apply of the more accurate methods. Of these two the inclined-plane method is the more rational and probably the more dependable.

3. The direct three-station average and inclined-plane average give only about one-half as large algebraic errors as single-station methods. In regions of low to moderate rainfall variability the average algebraic error of these methods are no larger than those for the more refined methods.

4. Because of their simplicity and the avoidance of the labor of using normals, the direct three-station average and inclined-plane methods are the ones best adapted for use in regions of low or moderate rainfall variability.

5. In regions of high rainfall variability the arithmetic, algebraic, and total percentage errors are generally the least for interpolation methods involving the use of Fournie ratios and normals.

As nearly as good results can, however, be obtained from the use of contemporaneous records only by means of weighted correction ratios as applied in the Horton and Leach methods. Considering the reduced labor usually involved in the application of these methods through the avoidance of using normals, they appear to be the methods best adapted for regions of high rainfall variability. Of the two, the Leach method is apparently somewhat the better.

CONCERNING THE RELATION BETWEEN THE DURATION, INTENSITY, AND THE PERIODICITY OF RAINFALL.

By Prof. PETER PHILIPOVITCH GORBATCHEV.

[Rostov on Don, Russia, May 27, 1923.]

According to theoretical calculation, a definite quantity of water vapor brought by cyclonic air currents from the point of evaporation to the point of observation in form of a cloud, with a degree of humidity just sufficient to begin condensation, can produce precipitation, the general amount of which, h and the duration, t, can vary with the length of the cloud and the velocity of the air currents in which it floats. But for all this equally possible rain, that is, for rain precipitated from the same cloud, there must exist a definite relation between the average intensity of precipitation during the time of the rainfall, $i=h/t$, and the duration of that rainfall, t, that is

$$i_1\sqrt{t_1}=i_2\sqrt{t_2}=i_n\sqrt{t_n}=\Delta$$

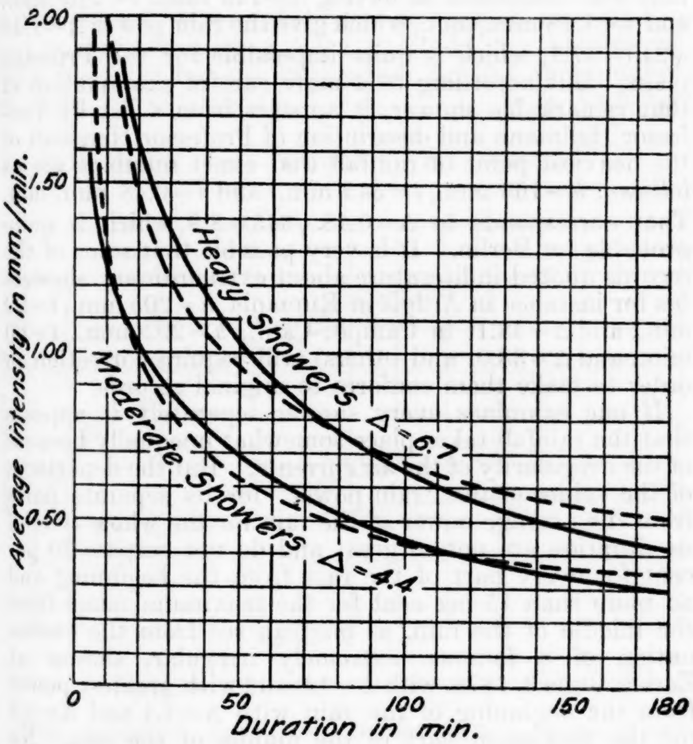

FIG. 1.—Curves of intensity ($i=\Delta/\sqrt{t}$) of showers in Middle Germany (after Hellmann).

Here the quantity Δ depends on the one hand, on the quantity of the drifted rain material in the cloud, and on the other hand on the angle of ascending cyclonic motion of the cloud, which is a result of topographical conditions, but it does not depend on the velocity of the storm nor on its length. Therefore, the quantity Δ for every separate cloud passing above a given place is a constant quantity and is characteristic of it and, therefore, of the whole series of rains equally possible from this cloud.

If the quantity of the water vapor in the cloud happens to be the maximum that is ever possible in the given period, owing to the extreme evaporation as a result of insolation and other favorable conditions, then surely all the equally possible precipitation from such a cloud will be stronger than from every other cloud. Consequently, the values of the intensities of such precipitations for corresponding periods will be the limit for the given place during the time considered, the same as the quantity Δ itself. If the quantity Δ is known, it is possible to construct a theoretical curve for limiting intensitities after the equation, $i=\Delta/\sqrt{t}$ for different durations.

If one compares the results of investigations of different authors concerning the limiting intensities for different places, obtained by selecting from meteorological records for a given period of time the observed intensities for each duration, it will appear that in all cases, those limiting intensities, expressed by empirical formulae or curves or tables, come always very near and sometimes coincide with theoretical curves constructed after the equation $i=\Delta/\sqrt{t}$ by corresponding average value of Δ. So, for instance, expressing h and i in mm. and t in minutes, the curves of the heavy showers for North Germany, according to the formula of Hellmann, will correspond to the value of $\Delta=6.7$ and the curve of moderate showers will be $\Delta=4.4$. (Fig. 1.) The curve of heaviest rains for the United States of America, after A. J. Henry, corresponds to $\Delta=12.4$, and for the heaviest showers in the southwest of Russia $\Delta=11.7$ (after Dolgov). According to A. Follwell the curves for moderate showers for North America will be as follows: Central States $-\Delta=5.2$; New England, $\Delta=3.5$ (Fig. 2); and for South Atlantic States, $-\Delta=5.7$. Berlin has $\Delta=3.0$ (according to Frühling for the space of a year) and Darmstadt $-\Delta=2.3$ (according to Heyd for the space of a year).

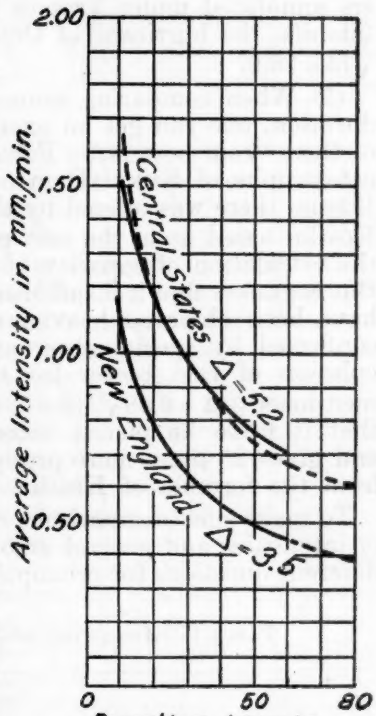

FIG. 2.—Curves of intensity of moderate showers in the United States (after Follwell).

According to the condition $i=h/t$ one can present the expression for Δ in other terms: $\Delta=h/\sqrt{t}$ and $\Delta=\sqrt{hi}$. The last equation shows that the quantity Δ is simultaneously determined by the proportions of the two most important characteristics of the rain, that is, the quantity of the rain (the quantity h) and by the intensity of the rainfall (the intensity i). Therefore the quantity Δ may be called the "rain power" as similarly in electrical terminology the products of quantity of current (in amperes) to its intensity (in volts) gives the effect or the power of the motor.

This determination of the "rain power" is convenient while working with meteorological quantities and gives an exact criterion: (a) for the classification of rains; (b) for comparative estimation of different rains, and (c) for the verification of meteorological records if doubtful.

(4) According to the "rain powers," calculated by the author for more than 200 cases of separate rains and their practical estimation by descriptions conforming to established determinations for different degrees of precipitation, it is possible to divide the rains after their "power" into the following categories (if h and i be expressed in mm. and t in minutes).

Type of precipitation.	Characteristics.	Rain power, Δ.	
		From—	To—
1. Small rains	Of importance only for rural economics.	0.0	1.0
2. Ordinary rains	Occur yearly	1.1	3.0
3. Moderate showers	Produce streams in natural cavities	3.1	5.0
4. Heavy showers	Are mentioned in records as rare phenomena.	5.1	7.0
5. Extraordinary showers	Disastrous results	7.1 and higher.	

After the observation for the plains of Europe, one can take $\Delta=12$ as the upper limit for power of extraordinary showers (Bobersberg in Brandenburg, June 21, 1895, $\Delta=i\times\sqrt{t}=1.08\times\sqrt{120}=11.8$). The upper limits for the "power" of extraordinary showers in North American are approaching the same number (Merrill, Wis., July 24, 1912, $\Delta=0.62\sqrt{450}=13.2$). In mountainous countries the extraordinary showers reach the power of $\Delta=16$ (Nieder Marsberg in Provinz Westfahlen, August 6, 1897, $\Delta=2.29\sqrt{45}=15.4$). The showers annotated under Tropics have the power of $\Delta=26$ (Manila, the hurricane of October 19–20, 1882, $\Delta=6.77\sqrt{15}=28.9$.

(5) When comparing rains of different intensity and duration, one can get an exact estimate by comparison of their "rain powers." For instance, after the terrible catastrophe of Kukui Dam on Moscow Kursk railway, Russia, there was offered by the Ministry the formula of Köstlin based upon the rain power $\Delta=0.96\sqrt{10}=3.0$ for the calculation of capacity of pipes or railway culverts. But engineers find it insufficient in practice because there have been observed heavier showers which have been confirmed by special observations. But from the calculation of rain power for the Kukui shower, above mentioned ($\Delta=0.48\sqrt{240}=7.4$) one can see at once that it is to be placed among extraordinary showers and gives 25 times more precipitation than would follow from the formula of Köstlin.

To make such comparisons easier we give below tables of intensities and general amounts of precipitation with different durations for principal categories of rain power.

TABLE 1.—*Average intensities $i=\Delta/\sqrt{t}$ (in mm./min.).*

Categories of rain power $i=\Delta/\sqrt{t}$.	Duration of rainfall t =					
	15 minutes.	30 minutes.	45 minutes.	1 hour.	3 hours.	6 hours.
1.0	0.26	0.18	0.15	0.13	0.07	0.05
3.0	0.77	0.55	0.45	0.39	0.22	0.16
5.0	1.29	0.91	0.75	0.65	0.37	0.27
7.0	1.81	1.27	1.04	0.90	0.52	0.37
12.0	3.10	2.18	1.79	1.55	0.89	0.64
16.0	4.13	2.91	2.38	2.06	1.18	0.85
26.0	6.71	4.73	3.87	3.35	1.92	1.38

TABLE 2.—*General amount of rainfall $h=\Delta\sqrt{t}$.*

$h=\Delta\sqrt{t}$.	Duration of rainfall t =					
	15 minutes.	30 minutes.	45 minutes.	1 hour.	3 hours.	6 hours.
1.0	3.9	5.5	6.7	7.7	13.4	19.0
3.0	11.6	16.4	20.6	23.3	40.3	56.9
5.0	19.4	27.4	33.6	38.8	67.1	94.9
7.0	27.1	38.4	47.0	54.3	93.9	132.8
12.0	46.5	65.8	80.5	93.0	161.0	227.6
16.0	61.9	87.7	107.4	124.0	214.7	303.5
26.0	100.6	142.5	174.5	201.5	378.9	493.2

Since we know the largest possible "rain power" for different countries, we can verify the accuracy of separate observations. For instance, there had been doubts about the shower at Nagartava (prov. Cherson, Russia) July 9, 1921, which has been recorded as having $h=99$ mm., $t=30$ min. and $i=3.3$ mm./min. If one calculated the rain power according to it, it will be $\Delta=3.3\sqrt{30}=18.1$. As there are never on the plains of Europe showers with Δ more than 12.0, and in mountainous countries no more than $\Delta=16.0$, so there must be obviously a mistake in this record. And, indeed, there is an exact record in the detailed revision of Professor Klossovsky from which one can see that the rain lasted not for 30 minutes but for 4 hours and 30 minutes or 270 minutes, so that the intensity will be only $i=0.4$. Then the rain power will be $\Delta=0.4\sqrt{270}=6.6$ what [which] is a rather heavy but quite possible shower for the given country. There is also a shower quoted in the list of Professor Friedrich, that took place in Berlin, April 14, 1902, that was mentioned as having $h=143$ mm., $t=210$ min., and $i=1.18$ mm./min., which give the rain power $\Delta=1.18\sqrt{210}=17.1$, which is quite impossible for the Prussian plain. But according to a more careful examination of that remarkable shower, it appears from a list by Professor Hellmann and description of Professor Hergardt of the heaviest point of rainfall that exact numbers are as follows: $h=166$ mm., $t=345$ min., and $i=0.48$ mm./min. That corresponds to $\Delta=0.48\sqrt{345}=8.9$ which is quite probable for Berlin. It is very possible that some of the records quoted in literature about extraordinary showers (as for instance in Ardgis in Rumania, $h=205$ mm., $t=20$ min., and $\Delta=48.1$; in Campo, Calif., $h=292$ mm., $t=60$ min., and $\Delta=38.0$, and others) will require correction in order to make them conform to original records.

If one examines every shower separately it appears that the rainfall takes place somewhat unequally because of the irregularity of the air currents. But the departures of the values of the "rain power" for its separate parts from the average power of the rain for the whole time of its duration are not so great and do not surpass 10 per cent for every part of the rain from the beginning and no more than 15 per cent for the maximum taken from the middle of the rain, as one can see from the examination of a famous, extremely irregular, shower at Zurich, June 3, 1878, with $\Delta=4.0$ and with greatest power from the beginning of the rain with $\Delta=4.4$ and $\Delta=4.6$ for the maximum part in the middle of the rain. No more than such departures are observed among other rains, when comparing their average power with the largest in maximum parts. From this it follows that for determining rain powers one has always to calculate it as average power for the whole rain and not divide it into heavy and small parts; that for practical purposes, for technical calculations, for instance, one can assume without great error that the relation between the duration and the intensity of the rain is maintained in every part of it, and that the value of the "rain power" remains the same as for the whole rain, and for every part of the duration taking it from the beginning of the rainfall.

Up to this point the "rain power" Δ has been examined by the author independently of the length of the period of meteorological observations. But if one compares the limiting rain powers for the same point in different years, it will appear that the limits will be greater the longer the period of the observation. This is explained by the fact that the quantity Δ depends, as said above, upon the largest amount of drifted rain material; that is, from the largest evaporation and the strongest cyclones, which

depends for itself upon the quantities of caloric energy emitted by the sun. Professor Brückner proved the periodicity of this phenomenon with the change of cold and warm years during the period of 30–35 years and related it to the sunspot maximum. But the comparison of spring floods of rivers shows that the greatest maxima repeat every two Brückner periods; that is, every 60 to 70 years; there are also some indications of two periods for the maxima of the solar spots, about 11 and about 60 years, that appear in the complete fluctuations in the curve of periodicity. Therefore one must wait also for the change of limiting "rain power," the period of about 35 or 70 years.

If one examines the number of the occurences exceeding some certain "rain power" by other heavier rains, a remarkable regularity is discovered; for example, if calculating the "rain powers" from their complete list for the given country during the period n years and tabulating them according to their powers beginning from the largest, we obtain K_1, K_2, and so on, cases for every observed power. If we take every power that exceeds the nearest next class of $\Delta_n - 0.1$ and add the number of cases, we have for any rain power $\Delta_n - 0.1$ the number of cases of exceeding $= K_1 + K_2 \ldots\ldots + K_n = \Sigma K$ for the whole period of n years and $\frac{\Sigma K}{n}$ for 1 year.

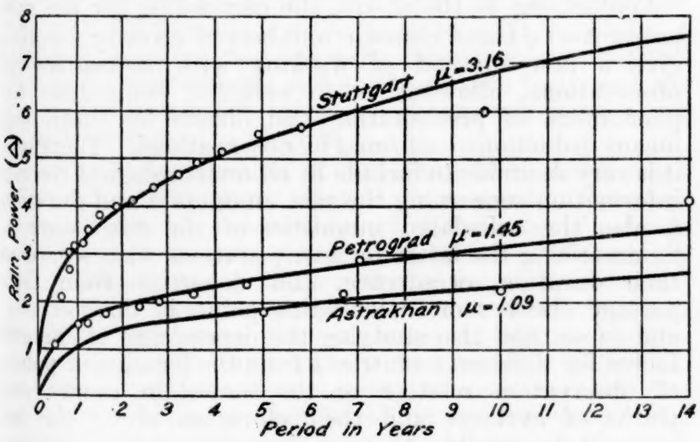

FIG. 3.—Curves of periodicity of "rain power" ($\Delta=\mu\sqrt[3]{p}$).

This quantity expresses the frequency of only one exceeding the given "rain power" in the course of one year $\frac{\Sigma K}{n}=\frac{1}{\rho}$ and the inverse quantity ρ will be the period for the only one exceeding the given "rain power." If we set down graphically the observed rain powers Δ as ordinates taking the periods ρ (the excedance interval) as abscissae the curves obtained for different countries will be all cubic parabolas, which means that there exists an equation $\Delta=\mu\sqrt[3]{\rho}$ where μ is a constant climatic factor for the country, expressing the correlation of all its climatic and geographical conditions. So, for instance, these climatic factors have proved to be for Hanover, $\mu=2.90$; for Stuttgart, $\mu=3.16$; for Petrograd, $\mu=1.45$, and for Astrakhan $\mu=1.09$. (Fig. 3.)

One may note that it follows from the corresponding equations that the climatic factor μ exceeded the "rain power" Δ no more than once a year, and generally the "rain power" Δ can be expressed as the theoretical intensity, corresponding to the precipitation of the whole amount of rain in the course of one minute. As an instance of the calculation of the climatic number μ there are given tables of its deduction for the city of Stuttgart from the records of 29 years' observation.

TABLE 3.—*Showers at Stuttgart, 1875–1903.*

Δ	9.3	7.4	6.0	5.7	5.6	5.3	5.0	4.0	4.5	4.3	4.1
Number of cases K	1	1	1	2	1	1	1	1	2	2	2

DEDUCTION OF CLIMATIC NUMBER, μ, FOR STUTTGART.

Observed rain power Δ.	ΣK	$\frac{m}{n}=\frac{1}{\rho}$	ρ	$\sqrt[3]{\rho}$	$\mu=\Delta/\sqrt[3]{\rho}$
More than 9.2	1	1/29	29	3.07	3.0
More than 7.3	2	2/29	14.50	2.44	3.0
More than 5.9	3	3/29	9.67	2.13	2.8
More than 5.6	5	5/29	5.80	1.80	3.1
More than 5.5	6	6/29	4.83	1.64	3.3
More than 5.2	7	7/29	4.15	1.61	3.2
More than 4.9	8	8/29	3.63	1.54	3.2
More than 4.8	9	9/29	3.22	1.48	3.2
More than 4.4	11	11/29	2.64	1.38	3.2
More than 4.2	13	13/29	2.23	1.31	3.2
More than 4.0	15	15/29	1.93	1.25	3.2

If one knows the climatic numbers for the given country, one can calculate from the equation $\Delta=\mu\sqrt[3]{\rho}$ for every period of time ρ such "rain power" Δ, as can be exceeded more than once for this period of time and that can be considered the limit for this period of time, and from which one can calculate from the equation $i=\Delta/\sqrt{t}$ the limiting possible intensities for every duration during this period of time. This is very important for technical calculation. So, for instance, in Germany one assumes for the projects of sewerage that the sewers are to overfill no more than once a year and on the main streets no more than once in two or three years. According to the author's opinion one should take as a period for the single overfilling no less than five years, and for the more dangerous cases one has to increase the period as follows, for instance: For deep valleys within the town, 20 years; for pipes and bridges for roadway, 35 years; and for railways, the largest period, 70 years.

Moreover, one can theoretically obtain from the equation $\Delta=\mu\sqrt[3]{\rho}$ some interesting deductions concerning the recurrence of rains of different powers, concerning the average yearly amount of precipitation, and lastly, concerning the largest possible rain powers which are justified by actual observations.

(10) Yearly recurrence of a group of any rain powers limited from Δ_0 to Δ_1 is expressed by the equation $\frac{1}{\alpha}=\mu^3\frac{\Delta^3_0-\Delta^3_1}{\Delta^3_0\Delta^3_1}$, and inversely — α will be the number of years in the period of only one occurrence of any rain power from this group. Thus theoretically calculated numbers of cases of yearly occurrence nearly coincident with observed actual cases according to the rain records are proven in the table below for Stuttgart and Petrograd, but it is necessary to remark that there are not mentioned a great many small rains in the record of Stuttgart, and that heavy showers (with Δ more than 5.0) are very scarce in Petrograd and as, according to calculated yearly occurrence, $\alpha=0.02$ they happen only once in 50 years, it is difficult to expect that they can be mentioned in a rain record of 19 years.

Yearly occurrence.	$\frac{1}{\alpha_0}=\mu^2_0\,\frac{\Delta^3_0-\Delta^3_1}{\Delta^3_0\,\Delta^3_1}$			
Categories of rains.	Stuttgart.		Petrograd.	
	Theoretical.	Actual.	Theoretical.	Actual.
Ordinary rains (1.0–3.0)	30.4	2.1	2.9	2.9
Moderate showers (3.0–5.0)	0.91	0.83	0.08	0.07
Heavy showers (5.0–7.0)	0.16	0.17	0.02	0.00

The average yearly amount of precipitation evidently consists of the sum of precipitation of all categories of rains corresponding to their yearly occurrence and one can express it theoretically by equation $H=S\sqrt{\mu^3}$. If we compute the quantity S for four towns with continental climate we obtain for Stuttgart $S=110$, for Hanover $S=116$; for Ekaterinoslav $S=120$, and for Astrakhan $S=131$. Therefore, one can take for the central region of Europe the middle number with sufficient accuracy and obtain the equation $H=120\sqrt{\mu^3}$. But for countries with humid sea climate the quantity S departs considerably from its average value (for instance, for Petrograd $S=271$). Probably there fall and are recorded very small rains which in a drier continental climate are evaporated without reaching the surface of the earth and therefore escape being recorded.

(12) The largest possible "rain power" for a given place will evidently be such a power as is not surpassed in the course of the complete cycle of periodicity of precipitation for ρ years, and consequently will be $\Delta=\mu\sqrt[3]{\rho}+0.1$. In case the exact climatic number of the country μ is unknown, it can be substituted by yearly average quantity of precipitation H (from the equation $H=120\sqrt{\mu^3}$), from which it becomes approximately $\Delta=0.041\sqrt[3]{H^2}\sqrt[3]{\rho}+0.1$.

The complete cycle of periodicity of precipitation makes up, according to Brückner, $\rho=35$ years, and then the maximal rain power will be $\Delta=0.13\sqrt[3]{H^2}+0.1$. But according to the opinion of the author the complete cycle of periodicity must be a double one—that is, $\rho=70$ years. The maximum possible "rain power" will be somewhat larger, namely, $\Delta=0.17\sqrt[3]{H^2}+0.1$.

For the verification of this formula there were calculated by the author the "powers" of all remarkable showers known to him, from which appeared to be that for the majority of actual observations the "rain powers" do not surpass the calculated value of their power for the period of $\rho=35$, although approaching it closely. That could be expected because the majority of exact meteorological reports seldom embraces a period of observations larger than for 30 to 40 years. Only in nine cases quoted below the actual maximum "rain power" was larger than the theoretical for the period of $\rho=35$ years, but did not reach the theoretical power calculated for the period of $\rho=70$ years.

Country.	Date.	Yearly H.	Theoretical.		Actual.
			Max. $\rho=35$	Δ $\rho=70$	Δ max.
		Feet.			
Budapest	June 26, 1875	435	7.6	9.9	8.5
Paris	Sept. 20, 1867	483	8.1	10.6	9.2
Treuenbrietzen (Brandenburg)	July 31, 1897	506	8.4	10.9	10.8
Vienna	July 21, 1912	566	9.0	11.7	9.9
Breslau	Aug. 6, 1858	585	9.2	11.9	10.1
Schwerin	May 11, 1870	614	9.5	12.4	11.4
Karlsruhe	June 23, 1885	723	10.6	13.8	13.0
Geneva	May 30, 1827	822	11.5	15.0	12.1
Nieder Marsberg	Aug. 6, 1897	975	12.9	16.8	15.4

TABLE 5.—*Rains at Stuttgart recorded during the period 1875–1903, according to Dr. Th. Heyd.*

[The intensity of precipitation in mm./min. is calculated by the author.]

Dates.	Intensity of precipitation (mm./min.).	Quantity of precipitation (e/sec. ha.).	Duration of precipitation (mins.).
1875—Aug. 31	1.20	200	7
1876—June 7	0.54	90	10
July 29	0.38	63	29
1877—June 20	0.67	112	34
June 21	1.20	200	60
July 14	0.44	74	15
July 18	0.35	58	10
1878—May 12	0.25	42	90
May 14	0.40	67	10
June 14	0.59	99	44
July 27	0.43	71	45
Aug. 7	0.34	56	17
Aug. 7	0.49	82	13
1879—Apr. 26	0.26	44	10
1880—May 14	0.62	104	10
June 11	0.55	91	35
July 1	0.59	99	16
Aug. 13	0.25	42	19
Sept. 8	0.28	47	10
Sept. 18	0.34	57	25
1881—July 9	0.76	124	12
July 16	0.22	37	75
1882—May 30	0.82	137	18½
May 30	0.73	121	12½
1883—May 8	0.52	86	20
July 10	0.85	142	22
July 10	1.04	174	15
July 23	2.50	417	3

Conforming to the above, the calculation for the rain power $\Delta=i\sqrt{t}$ and climatic numbers of country $\mu=\Delta\sqrt[3]{\rho}$ give a new method of working with meteorological observations, allowing us to establish some laws for phenomena of precipitation and obtain by theoretical means deductions confirmed by observations. Therefore, it is very desirable to include in all meteorological records information concerning the rain amounts h and duration t, also the calculated quantities of the rain power Δ. Summarizing the latter for many stations with regard to their duration, occurrence, and departure from their passage above some neighboring points of observations, and so on, and also studying the dependence of climatic factor for different countries μ from the location of points of observation relative to the mountain ranges and tracks of cyclones and their elevation above the sea level, it is possible to open new ways of exploration through the extremely abundant but hardly accessible virgin forest in which appears now the vast amount of meteorological observations concerning the rainfall of many thousands of stations in the whole world.

DISCUSSION.

By H. R. LEACH and R. E. HORTON.

[Voorheesville, N. Y., July 24, 1923.]

The suggestion that storms can be classified according to their "rain power" is worthy of further study. Once its true relation to other storm characteristics is established, and its frequency equation determined, most of the storm characteristics of a certain locality can be expressed in two or three simple equations, the constants of which may possibly hold for relatively large areas, as suggested in the paper.

The formula given for "rain power," $\Delta=i\sqrt{t}$ is not satisfactorily proven and is not in accordance with more recent intensity-duration formulas. The assumption that the power of a given storm is constant is not conclusively shown and it seems just as logical to assume that the power may suffer depletion as the storm progresses. The

intensity formulas more generally give the equation of an envelope curve embracing maximum intensities of all storms, rather than the intensity-duration relation of a single storm.—*H. R. L.*

The author evidently confuses storm with cloud in some degree. His first formula, $i=\frac{h}{t}$, is true of course of the total amount of precipitation in a storm where t is the total time, but the derivation of the basic formula for maximum rain intensity in a time interval t, given and used by the author, viz, that $\Delta=\frac{h}{\sqrt{t}}$, certainly does not follow from it. That is a form of expression sometimes used, especially in Europe, for relative rain intensities of equal frequency in storms of short duration. Of the hundred or more rain intensity formulas which have been published in the United States only a few take this form. More commonly an expression of the type $i=\frac{a}{b+t}$ fits the data better. My own preference is for a formula of the exhaustion type, $i=a\ e^{-kt^n}$. In each of the above formulas the intensity is finite, i. e., $\frac{a}{b}$ or a, for $t=0$; whereas the intensity formula used by the author gives an infinite intensity or precipitation rate for zero time, which is certainly incorrect. Nevertheless, the author's formula can be used to approximately or roughly represent rain intensity-time relations in short storms most anywhere, and so far as that feature of the paper is concerned he gives some data which have not hitherto appeared in English.

There is a suggestion of something very much more important in this paper; *that is, the proposition that there is for each locality a maximum or limiting value of nature's capabilities in the way of rain production*, but of course it has nothing whatever to do with the size of or amount of moisture in any cloud. Strangely enough, engineers invariably recognize the existence of this maximum but since no way seems hitherto to have been devised to determine its value, the majority of rain intensity and flood formulas are in such form that the existence of the maximum is not taken into account. I do not think the author's method of arriving at this so-called maximum value of Δ is satisfactory. Even if the Brückner cycle was much more perfect than it generally is, even then one cycle differs from another in magnitude of its maximum and minimum points to a considerable degree. There is, therefore, no certainty that the absolute maximum rain intensity for any interval may not somewhat exceed, though probably not much, any value observed, even in two Brückner cycles. I happen to have been studying this question of limiting or maximum possible rainfall rates very carefully. I fully believe in the existence of maximum values, as the author suggests, but I furthermore believe (and have worked them out to test my theory for many cases) that a frequency formula for various intensities can be devised in which the constants determined from the more frequent and better known observations will lead to a curve having an asymptote, the position of which is the limiting value of rainfall for the given duration, and this position can be determined.

Within the past few weeks Mr. Leach has been working out these limiting values of annual rainfall in this way for several of the longer New England rainfall records. In general the indicated maximum annual rainfall so determined is slightly, but sometimes only slightly, in excess of any value ever observed. Nearly all the records used cover seventy years or more.

To some extent the natural maximum limitations of rainfall, say for a single storm, can, I think, be approximated from meteorological conditions, although I have approached the subject entirely from a statistical viewpoint. In consideration of the importance of the subject, and the fact that I do not think there is a word in relation to it in print anywhere, a symposium on this very question—*Is there a limiting maximum amount of rain which nature can produce at each locality in any chosen time interval; and if so, how may this limit best be determined?*—would, I think, be fruitful of valuable results.

Gorbatchev's paper could be used in digest or abstract form to introduce such a discussion. It occurs to me that Bjerknes' Theory of the Cyclone, especially in relation to the formation of rain, points the way roughly to an analysis of the meteorological conditions which limit the possible amount of rain which can be produced at a given place during the passage of a cyclonic storm.—*R. E. H.*

CITY PLANNING AND THE PREVAILING WINDS.

CLARENCE J. ROOT, Meteorologist.

[Weather Bureau Office, Springfield, Ill., July 17, 1923.]

Much interest has been manifested during recent years in the city planning and zoning movement. The planning of cities is hardly a modern idea. As long ago as 1789 Maj. Pierre Charles L'Enfant, an engineer officer who had served with our troops in the Revolution, was commissioned to lay out a capital city for the young Nation. Washington to-day is an example of the advantages to be had in planning the future of our cities. Most of our cities were not planned, but just grew, and efforts are now being made to rectify the mistakes of the past and to plan for the future.

The city of Springfield, Ill., is about to adopt a city plan. The experts have completed the surveys and have submitted the tentative plan. This contemplates for the future city, among other things, a union railroad station, an industrial district, the creation of a large lake in the valley of the Sangamon River, and a civic center. The civic center is to be a memorial to Abraham Lincoln, and will occupy several blocks grouped about the Lincoln homestead. It is planned to have a wide boulevard lead from the union station, through the Lincoln civic center, to the State capitol building, and thence to the Lincoln tomb in Oak Ridge Cemetery.

In locating the industrial zone, Mr. Myron H. West, who supervised the work, placed it in the extreme northeast part of the city. Consideration was given to the source of water supply, proximity to coal mines and to railroads and terminals, housing conditions, and available sites for industrial plants. The matter of prevailing wind direction was an important factor, however, in choosing this location. The idea is to so locate industries that the smoke, gases, and noises will not be wafted over the city.

An examination of the 44-year weather record at the Springfield station discloses the fact that the prevailing wind direction is from the northwest during January

and February and from the south during all the other months. By months, the relation that the prevailing wind bears to the entire wind movement, expressed in percentages, is as follows: January, 52; February, 70; March, 43; April, 45; May, 70; June, 50; July, 41; August, 39; September, 73; October, 68; November, 43; December, 43. The following statement shows the second most frequent direction, where it is at all close to the prevailing: January, south; March, northwest; June, southwest; July, southwest; November, northwest; December, northwest.

A study of the diagram clearly indicates that the wind from any of the directions from which it usually blows will carry the smoke from the industrial zone out into the country, and that the smoke-bearing winds will blow over the city during but a small part of the time.

In discussing this subject Mr. West made the following statement:

> It is obvious that it is greatly to be desired that the residential sections of the city be to the windward rather than to the leeward of a large factory district, especially where the use of soft coal is prevalent. Even though electric energy be used to a large extent in such a factory district, there are always odors and noise emanating from such a factory district, which tend to make homes to the leeward thereof undesirable. A case in point is the large area of Chicago to the leeward of the stock yards. Unquestionably millions of dollars have been lost to property owners whose property has been affected by this condition.
>
> Some years ago we got out a plan for La Salle, Ill. The Illinois Zinc Co. had its plant on the river bank, and directly to the north on the hills lies the major portion of the residential section. The gases and smoke from this plant resulted in killing trees and shrubs along the streets and on private grounds. In another portion of the city trees and shrubs in a cemetery located to the leeward of a large cement plant have been seriously injured by dust and gases. In working out the industrial district in this case, we were careful to place it on plateau land well to the northeast where, fortunately, we were able to secure other requisites, such as belt line connection with railroads, fairly level land and adequate water supply.
>
> In the plan for Shreveport, La., we were compelled on account of local conditions to place the future factory district to the south of the city. We were careful, however, to zone the city in such a way as to force the better residential sections out of the path of the prevailing winds.

Some cities are not so fortunately situated in this respect as is Springfield. It is obvious that where a large body of water lies to the leeward of a city, preferred location for its industrial district can not be arranged. In the case of Chicago the prevailing winds are from the southwest during January, February, July, September, October, and December, and west in November. It will be noted that the winter months, when the smoke is probably the worst, are included in the southwest group of months. The prevailing wind is northeast during March, April, May, June, and August. The best residence sections have the advantage during these months.[1] A table showing the frequency of monthly prevailing wind direction at Chicago gives southwest 35 per cent of the total, and northeast 23 per cent. The large industrial plants at South Chicago and Gary are fortunately located. Because of the curvature of the shore line of Lake Michigan these plants are so situated that the smoke largely blows either to the southwest over open country or to the northeast far out over the lake and away from the city. The smoke from the west side manufacturing districts and railroad yards moves over the business center and north shore suburbs during the greater part of the year. This could only be avoided by locating these districts in what is now the best residence section of the city, the lake preventing the establishment of a manufacturing zone to the northeast of the business and residential sections.

At Milwaukee the prevailing wind is northeast during April, May, June, and August, but west and southwest throughout the remainder of the year. Here again the lake prevents the locating of smoke-producing industries in the most favorable place. The plants south of the business center and near the lake meet the situation fairly well. The trend of the shore line at Cleveland is largely northeast-southwest, and the lake offers no interference to the ideal placing of smoke producing industries. The prevailing winds are from the southwest during January, February, November, and December, west in March and April, and southeast from May to October, inclusive. With plants located in the extreme northeast part of Cleveland, the winds from any of the above mentioned directions would carry the smoke away from the entire city.

As planning and zoning projects are taken up in the various cities of the country consideration must be given to the matter of wind direction, and Weather Bureau officials will no doubt be asked to cooperate with the engineers in furnishing the desired information.

[1] Cox and Armington: The weather and climate of Chicago.

STIMULUS AND CONSERVATION OF ENERGY AS BASES OF MEDICAL CLIMATOLOGY.

By FRANZ BAUR, PH. D.

[Wetter-und Sonnenwarte, St. Blasien, Germany, April, 1923.]

SYNOPSIS.

The effect of stimuli on the natural defensive processes of the human body and conservation of its stock of energy, are the starting points from which medical climatology must develop, and which the latter has to deduce from observations of the physical condition of the atmosphere from clear comparative records. To do this it is necessary that all observations should relate to special physical properties of man, as well as his place of residence and personal habits, and that the description of climate hitherto customary, by giving only mean and extreme values, should give place to a description based on values intensities of stimulating power and of cooling power, and their respective durations.

It has been frequently pointed out, in recent times, both by medical men and meteorologists, that the method hitherto adopted of applying meteorological data to medical purposes is of little practical use. The deficiency is due partly to the different attitudes adopted by the professional meteorologist and the physician towards physical conditions of the atmosphere, and partly to the course of development of medical science during the last century. In both respects we seem to have reached a turning point. Medical climatology is about to give itself an independent position between meteorology and medical science, and to separate from the province of meteorology as a whole, those questions and results of research which are of especial importance to the physician.

A change has already become apparent in medical science, in serology and the therapeutics of proteins. For decades the chief objective of medical science was the complete understanding of the cause of diseases and the healing of the injured part of the body by means of specially adapted remedies, the so-called *specific* therapeutics. With medical science working on these lines, it was naturally only with difficulty that the completely unspecific *Climatotherapeutics* could be brought into line. Since, however, the value of increasing the energy

of the cellular tissues through the application of protein therapeutics (injection of albumins), and the therapeutics of stimulus arising from this, has found new and general recognition, the way has also been made clear for a wider and more complete understanding of the nature of climatic influences on both healthy and sick people. Although the different methods of healing adopted in protein, physical, climato-and balneo-therapeutics respectively, appear very different, yet they all have a *common basis*: *the effect of stimuli by which the natural defensive processes of the body are set in motion.* In this respect casein injections and irradiations are similar, as also are open-air cures and hydropathic treatment. The stimuli called forth by these methods differ, of course, in intensity and kind.

The recognition of the fact that the influences of meteorological phenomena on the human body chiefly consist of stimuli acting on the defensive processes, offers a direct hint as to how the peculiarities of a climate have to be grasped and set down, in order that the doctor may use climatic data for his purposes. It is the business of the physiologist to investigate the nature of the stimulating effects of climatic elements, that is to say, to attribute certain responses of the many and various defensive processes of the human body to different stimuli, which are determined by atmospheric conditions; and further, to decide for each element the downward limit of intensity beyond which no stimulus is perceptible. It is the task of the climatologist to determine the strength of the climatic stimuli for each locality. From this it is clear that the method adopted up to now of recording mean and extreme values of the different meteorological elements, is quite unsuitable for medical purposes. We must rather have a continuous record of measurements of all climatic elements in question, and then from such a record formulate a complete survey in the shape of tables or graphs, showing how often and when, in a given locality, during a certain period, certain intensities of the cilmatic stimuli are either not reached or exceeded. Let us take for example the electric vertical current, which passes from the atmosphere to man in the open, certainly constituting a valuable stimulus and tonic, and let us assume that, on the ground of physiological investigations, the defensive processes of the body are stimulated only at an electrical conductivity of the air equal to a, and that at a conductivity greater than $3a$, still more defensive processes enter into play. In this case it will have to be shown how often, and in what space of time, and for what duration, in each separate case, at a given place, the conductivity falls below a, lies between a and $2a$, between $2a$ and $3a$, and exceeds $3a$. As far as two or more cilmatic elements cause stimulating effects, which may be equal to or dependent on each other, it will not be enough to consider the elements separately, but will be necessary to consider them acting together, and to classify them again according to limits of stimulating power and duration.

By the side of this biological aspect of the influence of climate on man, we can and must place, however, another, purely energic aspect, since not only the nature and intensity of the climatic stimuli are involved, but also the demands made upon the stock of energy in the human body. The source of the total activity of the human body is after all the heat of combustion derived from food supply and from respiration. Part of this heat is consumed in keeping the body at a temperature of about 37° C. by means of various physiological expedients, in spite of the atmosphere which in our latitudes almost always exercises a cooling influence. The greater the total effect of all cooling factors (i. e. the "cooling power"), the greater is the demand on the heat energy of the human body, and the less energy is available for other activities. On this basis extensive experiments have recently been made in Davos by Dorno [1] with the "katathermometer" recommended by Leonard Hill,[2] and he calculated the cooling power for several other localities also, in Europe and North Africa, in accordance with Hill's formulae. The experiments were carried out with both wet and dry bulb katathermometers. Taking into consideration the half-moist epidermis and the moist mucous-membrane of man, it is obviously necessary to determine the cooling power with a wet kata thermometer. It is, however, very doubtful whether the method adopted by Hill of covering the bulb with wet muslin creates the conditions of evaporation corresponding

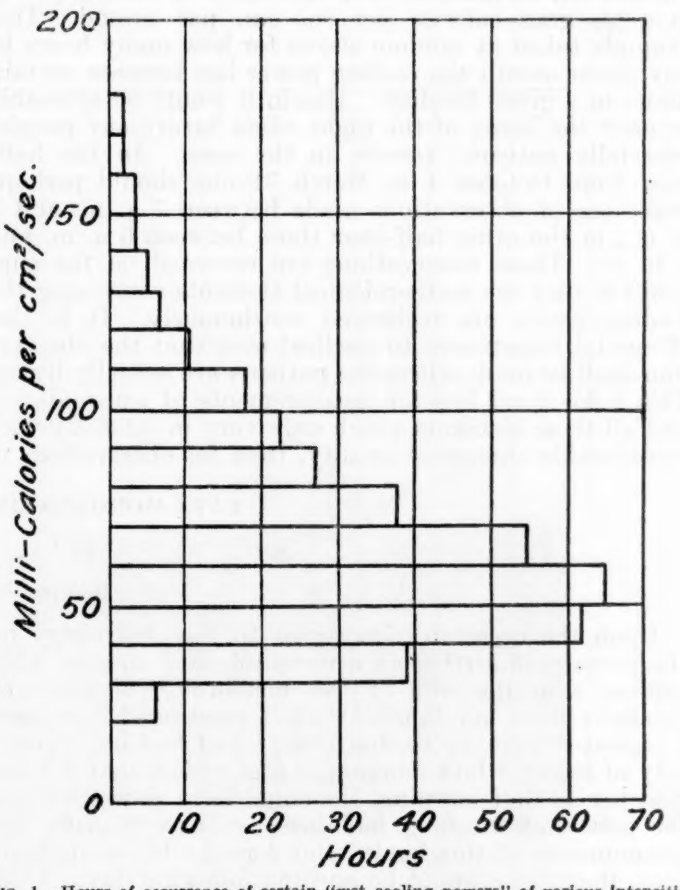

FIG. 1.—Hours of occurrence of certain "wet cooling powers" of various intensities between 7 a. m. and 7 p. m., in January.

exactly to those which prevail in the human body. In connection with this, and considering the great discrepancy between the size of the kata thermometer and the human body, it is still uncertain whether the velocity of wind really deserves the great significance as a cooling factor ascribed to it in Hill's formulae and Dorno's researches. In spite of this, however, the Hill-Dorno method of determining cooling power has meant a remarkable step forward in medical climatology. Thus Dorno's investigations produced the result, so important to the physician, that in the climate of a sheltered *elevated* valley (such as Davos), which acts as a powerful stimulus (too powerful for some patients), the human body provides itself much more easily with sufficient heat than on the North-German Coast (Borkum), and in

[1] Meteorologische Zeitschrift 1922, p. 344.
[2] Mo. WEATHER REV. 1920, p. 687.

North-German Lowlands (Potsdam), so that Borkum and Potsdam are much "colder" for man than Davos, although the latter shows on the average a considerably lower atmospheric temperature. The conclusion drawn by Dorno, however, that the climate of Davos as regards heat-production makes a smaller demand on the human body than the most sheltered places north of the Alps, is too general.

It is just as inadequate to take only average values in ascertaining cooling power as a measure of intensity of stimulus, since a number of secondary cooling factors of importance to the physician may be overlooked. In this case also it would be most useful to work out the frequency with which the limits are passed, and to represent this graphically as shown in the accompanying graph. On the axis of X the number of hours is marked off; on the axis of Y the limits of cooling power in $\frac{1}{1000}$ gram-calories per sq. cm. per second. This example taken at random shows for how many hours in any given month the cooling power lies between certain limits in a given locality. Herein it would be advisable to omit the hours of the night when hardly any people, especially patients, remain in the open. In the half-year from October 1 to March 31 one should perhaps make use of observations made between 7 a. m. and 7 p. m.; in the other half-year those between 6 a. m. and 8 p. m. These observations are recorded on the supposition that the meteorological elements composing the cooling power are registered continuously. It is also of special importance to medical men that the observation shall be made where the patients are actually living. This holds good less for measurements of sun-radiation and all those elements which only vary in intensity with considerable change of locality, than for observations of atmospheric temperature, since it is not possible to find an observation-point in every district which could be regarded as representative of atmospheres more remote; yet still more important is it for measurements of the wind, the sphere of influence of which is exceedingly limited. The researches of Hellmann and A. Peppler on wind-measurements carried out from the radio towers at Nauen and Eilvese, have shown that in the lower 16 meters, over level ground, the velocity of the wind increases considerably with the altitude; whereas in higher altitudes the increase in velocity is only very slight. From this, for the purposes of general meteorology and climatology the inference was doubtlessly correctly drawn that the measuring apparatus should be allowed to reach the atmospheric layers above 16 meters, since beyond this any difference in the height of the apparatus is of little consequence. It is, however, obvious that data concerning wind-velocities measured at a height of several meters above the roof level of any locality, and also cooling powers deduced from such measurements, are of no value to the physician. Similarly, Dorno's comparisons of cooling powers for different places lose in value since they are built partly on observations made at places never visited by patients. In health resorts, wind measurements and observations of cooling power should be made on *such* promenades and resting places as are chosen by patients. Of course, in order to fulfill the requirement of obtaining strict comparison between observations for different places, so important for the physician, it will not be possible to avoid making parallel measurements within the same district. It is also necessary to choose localities for observation with especial care, and describe them with minute accuracy.

FATA MORGANA ON THE NAGYHORTOBÁGY.

By Dr. Antony Réthly.

[Budapest, Hungary, May 31, 1923.]

Upon the occasion of my visit to Nagyhortobágy for the purpose of setting up a meteorological station, while talking with the wife of the meteorological observer, Adalbert Rácz, on June 7, 1922, I mentioned how much I regretted that, up to that time, I had had no opportunity of seeing a fata morgana. She replied that if I had told her so that morning, she could have shown me one, for just that morning had been an exceptionally fine phenomenon of this kind. But I might be assured, she said, that there would be one the following day. Upon asking for more details she told me that this phenomenon can be seen almost every day, if there is no rain. It is a continually moving sight, changing its place every moment, the objects run away, then return, suddenly disappear and reappear larger than before. To my remark "There is too strong a wind to-day", she answered "That's nothing, the better and more interesting it is." My expectation was aroused, I was quite incredulous, and I asked her to relate more particulars about the phenomenon, whereupon the lady invited me to go to the railway and look over the region.

Standing on the railway at 6 o'clock in the afternoon she showed me the whole panarama in order that I might see the region *when there was no fata morgana.* I observed the horizon with the unaided eye from ESE, to W. On the lower part of the annexed sketch (fig. 1) I reproduce what I saw. The view was thoroughly calm without trace of atmospheric unrest or of inverted images.

On the morning of June 8, I was occupied with the installation of the meteorological station. At noon I

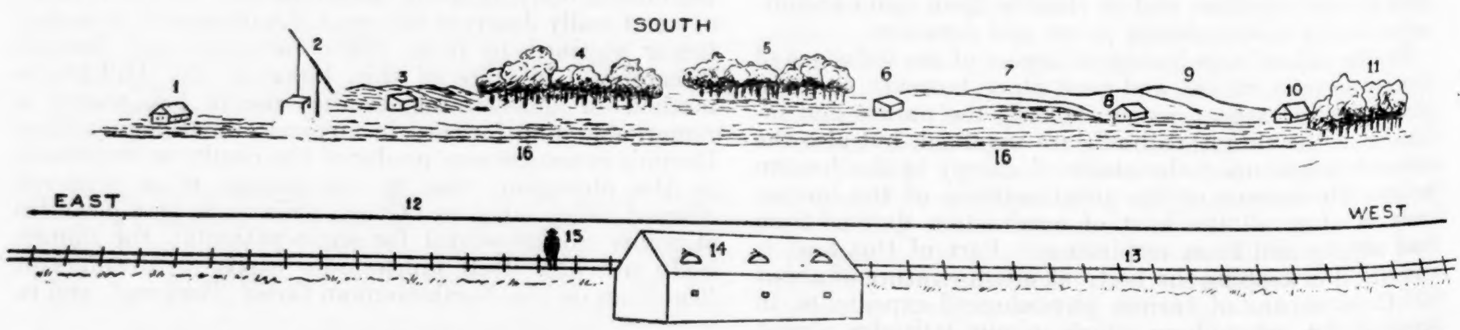

FIG. 1.—Sketch of the fata morgana on the Hortobágy. Explanation: (1), (3), (6), (8), (10) are huts; (2), a well;(4), (5), and (11), woods; (7) and (9), hills; (12), horizon; (13), railway;(14), a granary; (15), point of observation; (16), apparent water surface;.

Fig. 2.—Photograph of the fata morgana on the Hortobágy Plain in Hungary. (Photographed by W. G. v. Harangky.)

went out to the railway in order to see the region observed the previous evening. I did not go out with great expectation, because the sky was rather cloudy and the weather very windy. To my great surprise, however, I could observe an exceptionally fine specimen of fata morgana. It was beyond my expectations in every respect. About a third of the sky was covered with cumulus clouds. The wind blew from north with a force of 3 (Beaufort scale), while it had been continually north, force 3 to 4, in the morning.

Observing the horizon from east through south to west, I saw all objects elevated and in great unrest. (Upper part of fig. 1.) At several places water surfaces appeared in lively movement; for example, immediately behind hut No. 3, as well as half way between this hut and the spot where I was standing. Also before wood No. 5 a water surface appeared and the wood was somewhat raised above it. The fata morgana was intense, particularly in that part of the horizon which was east of the sun, but it was most intense in the direction of solar vertical. The fata morgana extended thus over the whole southern horizon, but its most intense part moved with the sun. I observed this on several occasions, at noon, at 1.30 p. m. and 4 p. m., when, in the east, the mirage was much weaker.

At 4 o'clock in the afternoon I saw a water surface in agitation. Waves moved from west to southeast, and they were so large and the mirage was so intense that at times the *huts and hills appearing on an elevated position* behind the water surface disappeared. Hill No. 9 was not visible during the whole time. Wood No. 11 was extraordinarily interesting. From time to time parts of this wood disappeared and reappeared again, and the trees seemed to move from west to southeast. A double wavy movement could be discerned; one component up and down and one approaching to, and receding from, the observer. Of all objects, wood No. 11 was lifted most, and behind it at a considerably greater distance I saw the church of Etyek aloft.

Beside the water surfaces mentioned, along the whole horizon, a large coherent water surface No. 16, appeared. Before wood No. 5 there was also a small water surface, behind which the wood detached from the ground, was standing entirely in the air. I estimated the elevation at least as high as the tree tops. No inverted image could be observed.

Before hill No. 7 there was a moving water surface. The hill itself showed a sight like that of the rising sun or moon when it is stretched out and extends at the side.[2] I saw this in the morning as well as in the afternoon, but it was more intense in the afternoon.

[2] Like Figure 37/c of Pernter's *Meteorologische Optik*, if we imagine the image of the sun, with its reflected image.

Looking northward I could distinctly discern St. Margaret's church, the mountain district of Tokaj, Eger, and Gyöngyös, and even with my feeble eyes I could see the sharp contours. But no fata morgana was visible in this direction.

About noon a herd of horses was driven to the draw well 2. When the horses traveled in procession, from time to time one or another of them, or the herdsman himself, disappeared for a moment, and I saw them at times farther forward or farther backward. It was a true cinema picture, rendered more complicated by the approach of the herd. Upon arriving at the watering trough near the well, the horses advanced like waves, then backed, then disappeared again. The herdsman with his horse also seemed to make an undulating movement, whereas in reality he stood at the same spot near the well; at times he seemed to move toward the east with the well for about two horse-lengths; at other times I saw him apparently farther back. This wavy movement was like that of wood No. 11—a very surprising phenomenon. After 2 o'clock the herd left the water trough, the receding horses disappearing for some moments only to reappear again higher or lower, but I could not discern an inverted image of any object during the entire day. At 7 o'clock in the evening the phenomenon was very weak, the water surfaces disappeared slowly, and the calm view of the Hortobágy appeared once more.

Mrs. Adalbert Rácz did not consider the phenomenon described above as of the finest. I consider it as a very interesting fact that on this day there was a lively wind (force 3), at times even stronger than force 4. The temperature was not exceedingly high, 82.4° F. (28.0° C.), and in course of the day the cloudiness increased until three to four-tenths of the sky was covered.

According to the records of the meteorological station at Nagyhortobágy from June 7 to July 31, fata morgana was observed on the following dates:

June 7 and 9	Very fine.
July 22 and 30	Do.
June 8, 18, 21, and 23	Fine.
July 21 and 31	Do.
June 12, 24, 25, and 30	Fair.
July 2, 3, 4, 5, 6, 10, 20, and 29	Do.

The fata morgana of July 22 was extraordinarily fine and lasted from 9 a. m. to 6 p. m. with a maximum temperature of 86° F. (30.0° C.), feeble east wind, relative humidity 25 per cent.

On July 30 from 10 a. m. to 5 p. m. a splendid fata morgana was seen, highest temperature 76.1° F. (24.5° C.), partly dull weather, brisk north wind, relative humidity 39 per cent.

MIRAGE IN LOWER CALIFORNIA.

Below is an account of a mirage seen by Observer James H. Gordon while on a trip to Lower California from Yuma, Ariz., his station, on June 26, 27, 1923:

"From Volcano Lake return was made to Mexicali for directions to reach Laguna Salada. Laguna Salada is a little known feature of this country. At its best it is a salt lake some seventy miles long and ten or twelve wide at the widest part. At its worst we judge it is a great salt flat of the same dimensions. It is fed by the drainage from the east slope of the Coast Range and the west slope of the Cocopahs and also, it is said, by occasional inflow from the Colorado at high water and from the Gulf at very high tides. Perhaps I should say that it lies in a valley hardly bigger than itself, with the Coast Range on the west and the Cocopahs on the east. We had little difficulty in finding it. Coming over a saddle in the Cocopah Range, the Laguna Salada springs into view. As we saw it there was a fringe of white salt flat a mile to a mile and a half wide about a very blue lake that stretched away farther into the south than we could follow. Far to the south there was much mirage, floating mountains with the inverted image below, distorted shore lines, etc. But the lake was a lake, unquestionably.

"This view was from a point fully two hundred feet above the lake bed. We drove down to the northern end

of the lake bed and left the car, intending to walk out to the water. The moment we dropped down onto the white salt surface the water disappeared. We walked out nearly a mile. There was no sign of water. The glaring white salt beds seemed to stretch away for miles, far in the south mountains floated in the air upheld on their inverted images. We gave it up at last. The lake had been a mirage, of course. From the car it was again visible and as we climbed up the steep grade it took on the same outlines we had first seen. Stopping the car at the crest of the hill, we walked south along the ridge for half a mile. The lake seemed immovable and of exactly the same shape. It was a mirage, of course, but I wanted to be sure, so climbed down the hill again, across a mile of sand dunes, lake still there, and down onto the salt, and there was no lake—just the mocking distant mirage. I walked out for three quarters of a mile. Underneath the salt crust there is a black alkali composition, greasy. It got softer as I went out, walking was very hard, temperature was 106 or more, not a breath of wind. I had to give it up. Coming back I passed a gasoline launch securely tied to a post fully a mile from the apparent water. The minute I was back on the dunes there was the lake. Fellows who had watched me from the top said I had gone but half way to it.

"We were getting short of time so turned back to Calexico. Stopping at the office of the Imperial Irrigation District there, I talked with Mr. Maddox, the assistant engineer. He said that there was almost certainly water in the Laguna Salada and just about where it had appeared to us to be, and not to be, as that was the lowest part. Apparently it was water. The white salt surface seems to have created a mirage of its own, and hidden the water."

SMALL TORNADOES NEAR CHEYENNE, WYO.

By GEO. W. PITMAN.

[Weather Bureau, Cheyenne, Wyo., June, 1923.]

Two small storms, evidently tornadoes, occurred near Cheyenne, Wyo., on the afternoon of June 2, 1923. The one that passed about 2½ miles to the southeastward of the city was seen by dozens of people, some of whom became much excited.[1] When first observed the funnel was at an altitude of about 40°, probably 45°, almost directly southeast of the local office. This was at 2:55 p. m., local time, and it had then the appearance of a long needle extending straight downward from the clouds, which soon assumed the shape of a long radish or carrot about 40 feet long and 2 feet in diameter, dangling from the clouds above. The storm moved north-northeastward over a path about 10 to 30 feet wide and about 3 miles long. At 3:10 p. m. the funnel was about 10° long, the bottom not reaching the ground, and the top approximately 35° above the horizon, and at 3:16 p. m. the clouds were apparently quiet. The funnel changed its appearance several times during its march. During the first and last parts of the storm it looked like a long smoky-black pillar standing almost vertical and reaching from the clouds to the earth. At another time when about one-third way in its march, it had the appearance of two cones set point to point, the bottom cone being nearly twice the size of the upper one and moving about 5° or 10° in the rear of the upper part of the upper cone.

As the storm moved over open country, the only damage was gaps torn in a few fences. At one point a barbed wire was wrapped six times counter-clockwise around a post and an end about 15 feet long left dangling. A light southwesterly wind of 13 miles an hour prevailed at the local office during the passing of the storm. A special observation at the time showed a barometer reading of 29.78 inches and a temperature of 70°, with a temperature of 73° at 2:00 p. m., and the temperature returned to 73° at 4:00 p. m. The barograph trace showed a gradual fall of 0.03 inch from 2:00 p. m. to 4:00 p. m. there being no surge whatever. A light sprinkle fell for about 15 minutes previously to the forming of the funnel, but very little during its passing, and the few drops of rain and hail that then fell were quite large, averaging from filberts to English walnuts in size. The first thunder heard was about the time or a little after the formation of the funnel and was apparently nearly overhead. The clouds immediately preceding the thunder were a smoky-black strato-cumulus type, with many individual clouds that gathered quickly, and a background of lower clouds, but higher, of a gray color. (Some state greenish but the writer saw no green.) No peculiar noises were heard, but these may have been counteracted by the railroad yards that lay in the southeast part of the city.

Another storm preceded this one by a few minutes. The few who saw it stated it moved east-northeastward over a path about 10 miles long and less than 40 feet wide, breaking up in the low hills about six miles northeast of Cheyenne. This storm also had a well defined funnel. It struck the barn on the Ever's ranch, doing about $200 damage.

TORNADOES IN NEW MEXICO, JUNE, 1923.

CHARLES E. LINNEY, Meteorologist.

[Santa Fe, N. Mex., July 16, 1923.]

Two small tornadoes occurred in the State during the month of June, 1923. The first, on the afternoon of the 7th, was observed at the ranch of Mr. A. R. Gray, 6 miles southeast of the village of Moriarity, Torrence County, N. Mex. The day was reported very cloudy, with rain to the west and a hard east wind during the forenoon. A cloud, which seemed to be different or separate from that from which the rain was falling, came up from the southwest at 1:35 p. m. Apparently there was no thunder, lightning or rain, but the pendent-shaped cloud was plainly visible and it left a plaster of mud over everything in its path. It traveled a distance of 7 or 8 miles, hit one farm house (country is very thinly settled), that of Mr. Gray, destroying it, with all household goods and some outbuildings. The loss is given as about $2,000. Mr. Gray reports that he only saw it strike the ground twice before it reached his place, when it moved on the ground for about a half mile. Hail occurred to the west of his place and a hard rain in the foothills far to the west.

The second storm occurred at Roswell on the afternoon of the 8th.

It has been the opinion of the people of the State that tornadoes do not occur within its confines, but two (or more) well-defined tornadoes were reported last year and thus far two have occurred this season, so that public opinion is in error in this matter.

(See following account by Mr. Cleve Hallenbeck.)

[1] Mr. Pitman's account of the two tornadoes observed near Cheyenne is welcomed, since it shows, first of all, that these storms in the dry regions of the West are much like overgrown whirlwinds and have none of the destructive characteristics of those which occur in more humid climates. The occurrence of similar storms in eastern Colorado and eastern New Mexico seems to fix definitely the western limit of tornadic storms along the eastern foothills of the Rocky Mountains.—EDITOR.

FIG. 1.—Tornado near Cheyenne, Wyo., June 2, 1923, from a point $1\frac{1}{2}$ miles distant.

FIG. 2.—Tornado near Cheyenne, Wyo., June 2, 1923, taken by a camper.

TORNADO AT ROSWELL, N. MEX.

By CLEVE HALLENBECK, Meteorologist.

[Weather Bureau Office, Roswell, N. Mex., June 15, 1923.]

The first tornado of record for the Pecos Valley of New Mexico and, according to pioneer residents, the first one ever known to occur in southeastern New Mexico, occurred at Roswell on the afternoon of June 8, 1923.

When first observed by the writer, at 3:48 p. m., the tornado cloud was about 15 degrees north of west, 7 miles distant, and suspended from near the southern edge of the nimbus area of an extensive, sluggish thunderstorm which at the time covered nearly half the sky. This thunderstorm had begun forming far up the west slope of the valley one and a half hours earlier, and was moving east-northeast against an east-southeast wind—a typical topographic thunderstorm such as is observed a score of times every summer. During the day, up to the time the thunderstorm began forming, strato-cumulus clouds moving in two directions were observed, the lower moving from the southeast and the upper from the southwest.

The tornado moved east-northeast, moving faster than the thunderstorm, and passed over the extreme northwest corner of Roswell, where it demolished a few houses, partly destroyed several others, and destroyed most of the barns, other outbuildings and windmills in its path. Two or three automobiles were wrecked, an airplane was stripped to its fuselage, a number of large trees were destroyed, and both wires and poles of electric lighting, power and telephone lines were torn down. Nearly a mile from the center of the tornado's path streets were blockaded by the branches, measuring up to 10 inches in diameter, that had been torn from the rows of shade trees lining the streets. The instrument shelters at two fruit-frost stations were blown over and two thermometers broken. There were no casualties, and only a few injuries. One entire family was badly mauled when the tornado played battledore and shuttlecock with the automobile in which it was riding, the latter became a shapeless wreck afterward, with its engine buried in the side of a hill.

When first observed by the writer, the tornado cloud was nearly vertical, with a ragged, truncated apex at least 150 meters from the ground. As it moved it became more and more inclined to the north, and when over the northwestern corner of the city was inclined fully 60 degrees from the vertical, while the base of the cloud had gradually grown wider, more ragged, and farther from the ground. In this manner it disappeared when about 10 degrees west of north of the station, becoming merged into the main cloud mass.

When nearest the station, the tornado was 1.5 mile due northwest, at which time a maximum velocity of 56 miles from the west was recorded at the station. Damage to buildings was confined to a path not more than 250 yards wide.

The tornado was accompanied by only a light rain, very little hail, and no thunder (except such as was due to its parent thunderstorm), but excessive precipitation, accompanied by a heavy fall of hail, followed along the same path an hour later. Buildings that remained standing in the path of the storm were plastered with mud on their west side, and spattered on their north sides, while both north and south sides bore scars and scratches made by flying gravel.

A number of individuals reported that three other tornadoes had previously formed in the southwest; that two of these were very short-lived, while the third passed directly over Roswell, high in the air, and when overhead "resembled a whirlpool in the clouds." These reports agree in all essentials, and very probably are true. The writer was busy, and saw but the last one, and very probably would have missed it had not an excited citizen called his attention to it.

The preceding account of damage done, etc., is compiled from accounts given the writer by people who visited the scene and not from personal observation, as he had no opportunity to inspect the damage himself.

DUSTFALL AT LUDINGTON, MICH., MARCH 25, 1923.

By CYRUS H. ESHLEMAN, Meteorologist.

[Weather Bureau, Ludington, Mich., June 25, 1923.]

A remarkable dustfall occurred at Ludington, Mich., and over an area extending east and west and a short distance apparently north and south, Sunday, March 25, 1923, between the hours of 4 and 6 a. m. Persons going out of doors noticed that the light snow which had fallen, amounting to about 0.4 of an inch, had a decided brownish tinge, and those who happened to be out earlier saw some of the dust come down with the snow. Capt. Michael Martin, of a Pere Marquette Line steamer, stated that when about 25 miles out from shore, bound for Manistee, he encountered the dust which came down like a great cloud of smoke.

The writer gathered some of the snow and dust and melted the snow. At first the sediment looked dark, but when it dried it again became brownish. Its composition was decidedly fine and powdery. Samples were sent to the University of Michigan, the Michigan Agricultural College, and the University of Wisconsin. An analysis was made also by one of the science instructors of the Ludington High School. All the reports of examination stated that organic matter was present. Numerous minerals were also identified. The general character, it was stated by Prof. Walter F. Hunt, of the University of Michigan, was that of loess such as is found at places in the Mississippi valley.

In the meantime numerous inquiries were mailed to Weather Bureau stations and other institutions or persons, with the view of learning the extent of the dust area. The replies to these inquiries indicate that the territory was 150 miles or more in length, from central Michigan across Lake Michigan into Wisconsin; and probably not more than 10 to 20 miles in width, though it is possible that to the north where snowfall was heavier the dust was thus hidden from sight.

The dustfall was unquestionably an unusual one, at least for this vicinity. A rough estimate of the total weight of the dust over the whole area, judging from that collected from a few square yards, would be at least 100 tons. Everywhere—on roofs, porches, sidewalks—after the snow melted the dust was noticeable. Even several months afterward on rough flat roofs some remained.

HEAVY RAINS IN SOUTHERN KANSAS, JUNE, 1923.

A. J. HENRY, Meteorologist.

[Weather Bureau, Washington, D. C., Aug. 1, 1923.]

The occurrence of heavy rains in the trans-Mississippi region is always an interesting meteorological event, whether considered as a purely meteorological phenomenon or in the light of its economic effects. It is to be remembered that, in Kansas, where abundant rain means so much to the agriculture of the State, too much rain, on

the other hand, means large loss to crops along river bottoms.

An account of the floods in the Arkansas Valley and the rains which produced it is given elsewhere in this REVIEW. (See p. 329.) Attention is here directed to the heavy rains of June 7-9, which apparently culminated at Wichita in a 24-hour fall of 6.68 inches on the 8th-9th. The magnitude of this rainfall was clearly a result of a favorable pressure distribution over the territory embraced between the Texas Panhandle in the southwest and lower Michigan directly to the northeast. A line connecting these two points passes directly over southeastern Kansas. The exceptional feature of the rainfall was the rather narrow zone of greatest intensity, which seems to have paralleled the Arkansas River valley, although full reports are needed to outline its exact distribution.

The pressure distribution.—By reference to Charts I and II (see track No. 1 of Chart I and track No. 3 of Chart II) it may be seen that on the morning of the 7th an anticyclone had advanced from Canada to South Dakota, as a result of which northerly winds prevailed over Kansas and Nebraska. In the succeeding 24 hours this anticyclone moved eastward to Minnesota, thus causing east and southeast winds over Kansas and at first light rain. Pressure was low in the Rocky Mountain region, and by the morning of the 9th a weak cyclone had advanced to the Texas Pandhandle. Central pressure in the anticyclone had increased to 30.30 inches in the meantime, thus producing a moderate gradient for southeast winds over Kansas. Surface temperatures were lower to the westward than to the east and southeast, and we must assume that the warmer and moister air that passed over Kansas overrode the colder air to the west and northwest, thus lowering its temperature to the dewpoint and causing continuous precipitation over a time that depended on the rapidity of movement of the cyclone and anticyclone, respectively. There was practically no movement of these, or very little movement on the 10th, and the rainfall continued in Missouri and Arkansas on that date.

The writer has previously found that heavy rains in Kansas [1] depend largely upon the slow movement of cyclones over the State in conjunction with anticyclones situated over Minnesota or the lake region.

From a consideration of these facts it seems reasonable and justifiable to believe that the occurrence of a pressure distribution favorable to heavy rainfall, heavy because continued for several hours, is a consequence of the orderly sequence of weather events and is not necessarily to be referred back to the pressure distribution at some previous time in a far distant place. In other words, that the vicissitudes of rainfall, whether light or heavy, are intensely local rather than general.

[1] MO. WEATHER REV. 43: 287.

NOTES, ABSTRACTS, AND REVIEWS.

THE SIZE OF METEORS.

[Reprinted from *Science*, New York, June 22, 1923, page viii, of supplement.]

That meteors as bright as the brightest star are no bigger than small bird shot is a conclusion drawn by Prof. F. M. Lindeman and Mr. C. M. Dobson, authors of a recent article in the *Proceedings of the Royal Society*. A meteor as bright as the moon would, they find, be only an inch in diameter and would weigh about 2 ounces.

As a result of their study, the authors conclude that the temperature of the upper atmosphere is much higher than was formerly supposed. It has long been known that the fall of temperature with altitude continues only to a height of about 7 miles, where the temperature is as low as from 60° to 70° below zero Fahrenheit. But from this altitude as high as sounding balloons have gone, which is about 15 miles, the temperature has remained about the same. This is what is known as the stratosphere or isothermal layer.

The recent investigators of meteors now conclude that this layer of fairly constant temperature extends up to a height of 30 miles, above which the temperature again rises, so that at altitudes of from 30 to 50 miles it reaches considerably above the freezing point, or about the average temperature at the earth's surface.

The density of the air at a height of 60 miles is calculated to be one-millionth of that at the surface. It is thought to be composed largely of ozone, and its high temperature is thought to be due to heating by the long-wave length heat waves from the surface of the earth.

GLACIOLOGY.

By C. S. WRIGHT and R. E. PRIESTLEY.

This splendid quarto volume of xx plus 487 pages, 179 figures, 291 halftone plates, and xiv folded maps, is one of the several reports of the British Antarctic Expedition under the lamented Capt. R. F. Scott.

The chief topic is, of course, snow and ice, but also there are many interesting references to Antarctic weather (a subject ably discussed in another report of this expedition by Dr. G. C. Simpson) and polar climates. Meteorologists especially will find a hopeful interest in the possibility of a logical seasonal forecast in the region of McMurdo Sound. "Unless the Sound freezes early, before the advent of winter establishes the large horizontal temperature gradient between sea and land ice, the high winds caused by this temperature gradient favour rather the retention of existing conditions and are strongly against the freezing of the Sound late in the winter. We see, therefore, that the climatic conditions of the autumn months—March and April—are, in McMurdo Sound, those which decide the winter conditions in this region. It is circumstances of similar nature which cause the large differences between the climate in any one region, from one year to another."

As is well known, it is far from self evident how enough precipitation is obtained over the Antarctic, and then retained, despite evaporation, summer melt, and blizzard drift, to keep the entire continent perpetually coverep with ice and snow. This puzzling problem is discussed, and the several methods by which precipitation is induced fully explained. Although neither accurate nor even approximately accurate measurements of either precipitation or ablation (loss by whatever process, except glacial flow) are possible in the Antarctic, the annual snowfall over the two to three million square miles of the low-lying barrier appears to be the equivalent of 12 to 24 inches of water. Approximately 7½ inches of this is the net annual gain that maintains the outward flow of the barrier ice.

In the chapter on the formation of ice crystals from vapor the important conclusion is reached that the form and nature of the snow or frost crystal depend essentially on the rate at which the crystal is grown, and not upon the temperature. Considerable attention is given to the

extensive occurrence in the ocean of frazil ice and anchor ice, each of which is rediscussed in the light of much additional information. Both fresh and salt water icicles are fully illustrated and explained, as are also the various types of ice foots, as the authors bravely (and correctly) call them, that form along the shore.

The mechanism of glacier motion is another of the reconsidered subjects, in which the merits and demerits of different explanations are considered. Those who found mental ease in the theory of fusion under high pressure and regelation under lower may be a bit disturbed by the concepts of crystal growth, free molecules, and varying vapor tension as contributors to the flow of glaciers. But the arguments advanced demand respect for these additional factors.

In so thoroughgoing a discussion the problem of giving names to the things described required careful consideration; hence we now have such terms as "continental ice," meaning an extensive sheet of ice so thick as to show little evidence of valley or hill beneath; "highland ice," also an extensive sheet, but thin enough to reveal the positions of all considerable ground irregularities; and so on through a goodly number of other names, including "cwm ice," meaning the ice in a cirque or bowl-like depression. But why, we wonder, this choice of an unlexiconed Welsh word *contra* its familiar Latin equivalent, especially when we haven't the slightest idea how to pronounce it?

The chapter on the structure of glaciers is delightful in its clear explanations of the origin of silt bands, some of which are more or less inclined—old fractures partially filled with windblown gravel and dust and then leaned far forward by the faster flow of the upper layers; also the blue or clear bands, resulting from shallow summer melting; white bands, caused by the collection of bubbles of air under the blue sheet; crevasses, and other structural peculiarities.

Fast ice, or ice beyond the shore but fast to the bottom, and the origin, westerly drift, and whole life history of the pack ice are also discussed in detail. The different kinds of icebergs, and the whole course of their disintegration, give material for an entire chapter. The tabular berg, a wandering ice plateau, sometimes over 100 feet high and 30 miles long, hence many fold the largest of all classes of icebergs, is peculiar to the Antarctic.

A final chapter of 53 pages is given to an illuminating discussion of the probable geological climates of the Antarctic. There is convincing evidence that at places the ice formerly stood 1,000 to 2,000 feet higher than it now does and also that it extended farther to sea. This, however, does not prove that the ice sheet formerly was 1,000 feet or more thicker over the whole of Antarctica. Perhaps the most interesting statement in this chapter is the belief of the authors that if the land of Antarctica were cleared of ice and nowhere was more than 1,000 feet above sea level the present snowfall could not result in glaciation; and that presently a relatively mild climate would prevail, much like that which pertained to Antarctica during most of the geological past.

The authors have also rendered fine service in bringing together in an appendix most of all that is known of the physical properties of ice.

Finally, the presswork, including the great number of halftones, is a model of excellence.—*W. J. H.*

THE AIR AND ITS WAYS.[2]

By Sir NAPIER SHAW.

This octavo of xx, 237 pages, xxviii plates, and 100 figures, a collection of a number of lectures, is his answer, the author says, to certain questions asked him by school teachers.

It is to be hoped therefore that these teachers will read this answer carefully—much of it several times—and then ask Sir Napier a lot more questions. The preparation of such illuminating answers, and making them literature as well as science, is hard work, nevertheless there is no excuse where *noblesse oblige*.

The book begins with 24 original and most instructive world charts of rainfall, temperature, dew point, cloud, pressure, and wind. These, we are told, were prepared for that *Manual of Meteorology* the author has in preparation, and which we are expectantly awaiting.

Then follow the 15 lectures, starting with "Meteorology for schools and colleges," and ending with "The artificial control of the weather." Between these sections, however, almost the whole field of meteorology is discussed. There is no mathematics in any of these lectures, but for all that there are many places that require the closest sort of attention, and where training in physics and mathematics would materially aid the reader in getting a clear understanding of the author's meaning. And this was inevitable, since the obvious and controlling purpose of the author in all these lectures was "the bringing of the ascertained and coordinated facts about the weather into relation with each other and thereby with the laws and principles of physics."

Three of these principles have got into meteorology largely through the persistent and wholesome influence of our author. These are the fact that, in the sense used by Jean d'Alembert more than a century and a half ago, the air moves under balanced forces; that every mass of rising air is continually depleted by turbulence; and that owing to the increase of potential temperature with elevation each convectional height is limited as by a ceiling, slightly elastic, but strong beyond possible rupture.

As above implied, this book is not, nor was it intended to be, a systematic course in the science of meteorology; nevertheless, it can be recommended to the uninitiated who wish to know something of that ever-present phenomenon, the weather; and urged alike upon novice and master who, having learned little or much, are keen to know more of the air and its ways.— *W. J. H.*

WEATHER IN EUROPE, JUNE, 1923.

From press reports that have appeared from time to time it is inferred that the month of June in Europe was attended by much cloud and rain and consequently little sunshine; low temperatures with frost in various parts of northern Europe and snow in the Alps also prevailed.

Subsequent reports show that in July high temperatures were experienced in England, France, Holland, Germany, and Italy.

All of this is merely saying that the weather of 1923 thus far has been characterized by great extremes rather than the steady change from season to season that is experienced in normal years.—*A. J. H.*

[2] Cambridge University Press, 1923.

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING JUNE, 1923.

By HERBERT H. KIMBALL, In Charge, Solar Radiation Investigations.

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, **48**: 225, and a note in the REVIEW for November, 1922, **50**: 595.

From Table 1 it is seen that direct solar-radiation intensities averaged decidedly below the normal value for June at Washington, D. C., and close to normal at Madison, Wis., and Lincoln, Nebr. But few measurements were obtained at the two latter stations, due to the prevalence of cloudy conditions. The low values obtained at Washington were due to the hazy condition of the atmosphere.

Table 2 shows that slightly more than the average solar and sky radiation for June was received during the month on a horizontal surface at Washington, slightly less at Madison, and decidedly less than the average at Lincoln.

Skylight-polarization measurements obtained at Washington on 11 days give a mean of 40 per cent, with a maximum of 56 per cent on the 30th. At Madison, measurements obtained on 5 days give a mean of 52 per cent, with a maximum of 65 per cent on the 30th. These are slightly below average values for June at the respective stations.

TABLE 1.—*Solar radiation intensities during June, 1923.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.										
	8 a.m.	77.8°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	77.8°	Noon.
	75th mer. time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
June 1	11.38	......	......	......	......	1.03	0.81	......	......	......	13.13
2	12.68	......	0.34	0.44	0.60	0.94	0.69	......	......	......	14.10
4	15.65	......	......	0.44	0.68	0.97	0.78	0.65	......	......	15.65
5	16.79	......	......	......	......	1.12	......	......	......	......	17.37
8	13.61	......	......	......	......	1.20	......	......	......	......	10.21
9	6.76	......	......	0.80	0.97	1.21	......	......	......	......	7.04
14	9.83	......	......	......	......	0.76	0.76	0.65	......	......	10.97
15	12.24	......	......	0.43	0.67	1.02	......	......	......	......	12.68
16	10.97	......	0.43	0.57	0.79	......	......	......	......	......	12.68
18	13.13	......	0.55	0.71	0.88	1.00	......	......	......	......	14.60
19	15.11	......	0.31	0.45	0.63	0.99	......	0.46	......	......	18.59
20	17.96	......	......	0.24	0.39	......	......	......	......	......	17.96
21	17.37	......	......	......	......	......	......	0.65	......	......	15.11
22	16.20	......	......	......	0.65	0.88	0.26	......	......	......	16.20
26	16.79	......	0.59	0.74	0.89	1.09	......	......	......	......	16.79
27	12.24	......	0.56	0.73	0.94	......	......	......	......	......	10.21
30	8.48	......	......	......	0.97	......	......	......	......	......	6.76
Means	......	......	**0.46**	**0.56**	**0.76**	**1.02**	**0.66**	**0.60**	......	......	......
Departures	......	......	**−0.16**	**−0.15**	**−0.12**	**−0.20**	**−0.27**	**−0.15**	......	......	......
Madison, Wis.											
June 13	11.81	......	......	......	0.86	......	......	......	......	......	12.24
14	14.10	......	......	......	0.90	......	......	......	......	......	15.65
19	17.37	......	......	......	1.00	......	......	......	......	......	15.65
21	17.96	......	......	......	0.85	......	......	......	......	......	18.59
22	18.59	......	......	......	0.99	......	......	......	......	......	17.37
23	17.96	......	......	......	0.75	......	......	......	......	......	17.37
26	11.38	......	......	......	......	1.45	......	......	......	......	9.83
27	13.13	......	......	......	......	1.35	......	......	......	......	15.11
29	7.29	......	......	......	......	1.43	......	......	......	......	7.04
30	8.81	......	0.89	1.00	1.11	1.37	......	......	......	......	12.24
Means	......	......	**(0.89)**	**(1.00)**	**0.92**	**1.40**	......	......	......	......	......
Departures	......	......	**+0.02**	**+0.04**	**−0.17**	**+0.09**	......	......	......	......	......

TABLE 1.—*Solar radiation intensities during June, 1923*—Continued.

Lincoln, Nebr.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th mer. time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
June 19	17.37	......	......	......	......	1.30	1.07	0.84	0.70	......	19.23
20	17.96	......	0.72	0.83	1.02	......	......	......	......	......	18.59
22	17.37	......	......	0.93	1.09	......	......	......	......	......	16.20
24	15.11	......	......	0.93	1.11	1.34	......	......	......	......	17.37
25	15.65	......	0.80	0.94	1.11	1.28	1.13	1.00	0.89	......	19.89
29	7.87	......	0.85	1.07	1.17	......	......	......	......	......	8.18
Means	......	......	**0.79**	**0.94**	**1.10**	**1.31**	**(1.10)**	**(0.92)**	**(0.80)**	......	......
Departures	......	......	**+0.05**	**+0.02**	**+0.02**	**−0.04**	**+0.01**	**+0.02**	**+0.04**	......	......

*Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
June 4	592	396	338	+90	−107	−199	−1,785	+925	+580
11	413	527	432	−101	+10	−120	−2,490	+997	−259
18	534	561	563	+12	+30	−12	−2,407	+1,205	−340
25	564	561	568	+44	+22	−16	−2,102	+1,359	−452

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was most unevenly distributed, as compared with the normal, as shown by observations made at land stations on the coasts and islands of the North Atlantic. At St. Johns, Newfoundland, the average barometric reading for June was about 0.25 inch below the normal, and on the Canadian and New England coasts the negative departures ranged from 0.12 to 0.15 of an inch. On the American coast, south of New York, as well as in the Bermudas, small departures occurred, while in the Azores and British Isles the pressure was considerably higher than usual.

Fog was unusually prevalent during the month, especially over the Grand Banks and along the American coast, north of the 35th parallel. It was reported on 19 days in the 5-degree square between latitudes 40°–45° N., longitudes 45°–50° W., on 20 days between latitudes 40°–45° N., longitudes 60°–65° W., and on 18 days in the square immediately to the westward of the latter. According to reports received the number of days on which fog occurred was also greater than usual over the eastern section of the steamer lanes and along the European coast, north of the 45th parallel.

With the exception of July, June is ordinarily the quietest month of the year over the North Atlantic. During the month under discussion the number of days with winds of gale force was somewhat greater than usual over the middle-western section of the ocean, due primarily to the cyclonic disturbance in the last decade of the month, that will be referred to later.

From the 1st to the 3d a well-developed depression was over Newfoundland and gales were reported from a limited area in the southerly quadrants. Storm logs:

Italian S. S. *Alberta:*

Gale began on May 31, wind S, 5. Lowest barometer 29.51 inches at 12:30 a. m. on the 1st, wind SW., 9, in latitude 36° 40′ N., longitude 50° 05′ W. End at noon on the 1st, wind NW. Highest force of wind 9; shifts S.-SW.-W.

American S. S. *Afel:*

Gale began on the 2d, wind SW. Lowest barometer 29.96 inches at noon on the 2d, wind SW., 7, in latitude 38° 38′ N., longitude 54° 04′ W. End on the 3d, wind W. Highest force of wind 8; shifts SW.-W.

Reports were received of moderate gales on the 1st over the region between Hatteras and the Bahamas, and on the same date they were also reported between the 20th meridian and the coast of France; comparatively high barometric readings prevailed in both localities.

From the 4th to the 7th moderate weather was the rule, except for a few sporadic winds of gale force.

On the 8th there was a well-developed disturbance central near latitude 45° N., longitude 35° W. On the same day a second LOW appeared with the center somewhere near latitude 57° N., longitude 15° W., although not enough observations have been received for an accurate determination. A number of gale reports were received from vessels in the region between the 45th meridian and the European coast. By the 9th these two depressions had apparently joined forces, and on that date as well as the 10th, the center was not far from the north coast of Scotland. Storm logs:

British S. S. *Tacoma:*

Gale began on the 7th, wind W. Lowest barometer 29.44 inches at 8 p. m. on the 8th, wind N., 9, in latitude 46° 26′ N., longitude 30° 20′ W. End on the 9th, wind NW. Highest force of wind 9; steady NW.

Danish S. S. *Virginia:*

Gale began on the 6th, wind SSW. Lowest barometer 29.09 inches at 11 a. m. on the 8th, wind W., 10, in latitude 56° 48′ N., longitude 18° 38′ W. End on the 9th, wind W. Highest force of wind 10; shifts W.-WSW.

British S. S. *Bloomfield:*

Gale began on the 7th, wind SW. Lowest barometer 29.61 inches at 11 a. m. on the 9th, wind W., 8, in latitude 48° 09′ N., longitude 18° 17′ W. End on the 10th, wind WNW. Highest force of wind 8; shifts SW.-W.-NW.

On the 9th a LOW appeared off the coasts of Nova Scotia and Maine; this moved rapidly northeastward, and on the 10th the center was near St. Johns, Newfoundland, while vessels between the 35th and 40th parallels and the 50th and 55th meridians encountered southerly to southwesterly gales. Storm log:

British S. S. *Bolton Castle:*

Gale began on the 10th, wind SW. Lowest barometer 29.97 inches at 2 p. m. on the 10th, wind SW., 8, in latitude 36° 50′ N., longitude 54° 49′ W. End on the 10th, wind W. Highest force of wind 8, SW.; steady SW.

From the 11th until the 21st summer conditions and light to moderate winds prevailed over the entire ocean, with the following exceptions: On the 12th and 13th there was a slight disturbance with moderate gales over a very limited area between the 55th and 40th parallels and the 55th and 60th meridians. Storm log:

American S. S. *West Haven:*

Gale began on the 12th, wind SSW. Lowest barometer 29.79 inches at noon on the 13th, wind S., 8, in latitude 39° 01′ N., longitude 55° 04′ W. End on the 13th, wind SW. Highest force of wind 9; shifts S.-SW.

On the 15th a westerly gale was reported by one vessel in the vicinity of the Bermudas. Storm log:

American S. S. *West Carmak:*

Gale began on the 15th, wind SW. Lowest barometer 29.90 inches at noon on the 15th, wind SW., 5, in latitude 33° 54′ N., longitude 64° 13′ W. End on the 15th, wind NW. Highest force of wind 8; shifts SW.-NW.

From the 22d to 28th the conditions over the western section of the ocean were most unusual for the summer season, as a deep depression remained in the vicinity of Newfoundland during that period, while the storm area varied in extent and intensity from day to day. Charts VIII to XI show the conditions from the 23d to 26th, inclusive.

The most severe weather of the month occurred on the 23d, when the western section of the ocean, north of the 35th parallel was covered by a severe cyclonic disturbance. Storm logs:

American S. S. *President Polk:*

Gale began on the 23d, wind NW. Lowest barometer 29.88 inches at 1 p. m. on the 23d, wind NW., 10, in latitude 40° 48′ N., longitude 58° 22′ W. End on the 23d, wind NW. Highest force of wind 10, NW.; steady NW.

The above gale was extremely freakish coming as it did with a high barometer and no usual sign. It made up a very heavy sea, the waves being as high as those seen during midwinter. Before things could be secured on board ship, some little damage was done by force of water coming on board.

British S. S. *Lackawanna:*

Gale began on the 22d, wind SE. Lowest barometer 29.03 inches at 3 a.m. on the 23d, wind SW., in latitude 41° 22′ N., longitude 46° 34′ W. End at noon on the 24th, wind WNW. Highest force of wind 11; shifts SE.-SSW.-WSW.

British S. S. *Norfolk Range:*

Gale began on the 22d, wind SE. Lowest barometer 29.63 inches at 9:23 a. m. on the 23d, wind S., 9, in latitude 47° 04′ N. longitude 39° 13′ W. End on the 25th, wind SSE. Highest force of wind 9: shifts S.-SSE.

On the 24th, as shown on Chart IX, the center of the disturbance had moved but little since the previous day, although the storm area had contracted considerably in extent, and was now practically confined to the eastern quadrants. On the 25th a secondary LOW appeared, Chart X, and heavy gales were reported from a limited area.

Japanese S. S. *Fukuyo Maru:*

Gale began on the 22d, wind SSE. Lowest barometer 29.42 inches at noon on the 25th, wind S., 9, in latitude 38° 47′ N., longitude 42° 42′ W. End on the 26th, wind WSW. Highest force of wind 10; shifts S.-W.

By the 26th, the relative position of the two LOWS had changed materially, as shown by Chart XI, and some vessels in the steamer lanes, between the 25th and 45th meridians encountered heavy weather, while a number of others in the same region reported only moderate winds. Storm log:

Belgian S. S. *Sunoco:*

Gale began on the 25th, wind SSE. Lowest barometer 29.43 inches at 5 p. m. on the 25th, wind SSE., 11, in latitude 43° 13′ N., longitude 41° 23′ W. End on the 26th, wind NNW. Highest force of wind 11; shifts SSE.-WSW.

From the 26th to 28th westerly to southerly gales were reported from the area between the Bermudas and Hatteras. Storm logs:

British S. S. *Parima:*

Gale began on the 26th, wind WSW. Lowest barometer 29.57 inches at 4 p. m. on the 27th, wind WNW., in latitude 36° 14′ N., longitude 72° 35′ W. End on the 27th. Highest force of wind 8; shifts WSW.-WNW.

American S. S. *E. L. Doheny III:*

Gale began on the 27th, wind WSW. Lowest barometer 29.54 inches at 6 a. m. on the 28th, wind S., 9, in latitude 32° 05′ N., longitude 72° 15′ W. End at 4 p. m. on the 28th, wind WSW. Highest force of wind 9, S; shifts WSW.-S.

On the 29th southerly to southwesterly gales prevailed over a limited area between the 37th and 42d parallels, and the 60th and 65th meridians.

NORTH PACIFIC OCEAN.

By WILLIS E. HURD.

June is usually associated with quiet conditions on the North Pacific Ocean. The typhoon is moderately infrequent, averaging only one or two annually in the month, and the gradient between the shallowing Aleutian LOW and the great high pressure area to the southward and southeastward is not particularly steep. In these respects June, 1923, was somewhat anomalous, for not only was there a far greater than normal number of typhoons formed in the Orient, but the Aleutian LOW was remarkably strong for the season. It persisted definitely until the third decade of the month, and during three or four days exhibited a depth comparable to that existing during the height of its winter activity, while it was attended by strong gales over a considerable expanse of ocean south of the Aleutian Islands. The North Pacific HIGH was fairly steady in its development and position throughout the month.

In the Hawaiian area quiet conditions prevailed. The trade wind was generally steady, and changes in pressure were of little importance. Only one disturbance appeared between the islands and the Californian mainland, and that was scarcely more than a mere depression which originated near latitude 35° N., longitude 135° W., on the 26th, and died out slightly to the northward on the

30th. At Honolulu the lowest pressure of the month occurred during this period, but the highest wind velocities were observed much earlier. The average hourly velocity for the month at this station was 10.8 miles, and the maximum reading was 30 miles from the northeast on the 11th. This was the driest June on record at Honolulu. Only 0.17 inch of rain fell, which was 0.75 inch below the normal.

The typhoons which occurred in the Far East during June have been fully discussed by the Rev. José Coronas, S. J., of the Manila Weather Bureau, in a paper which follows. It may be said, however, that in addition to the five typhoons he enumerates, there seems to have been a sixth which developed to the eastward of the Philippines about the 6th or 7th of the month. The American S. S. *Vinita*, eastward bound, on the 7th experienced a south wind of force 7, pressure 29.38 inches, in latitude 18° 08′ N., longitude 130° 38′ E. There was an accompaniment of heavy showers and high cross seas. The storm apparently first moved north-northwestward, then recurved and affected eastern Japan on the 9th and 10th. The highest reported force of the wind was 10 from the south, lowest pressure, 29.54 inches, observed by the American S. S. *West Jena* in latitude 36° 30′ N., longitude 141° E., on the 10th. On the 11th the typhoon moved rapidly northeastward, gradually inclining more to the eastward, and on the 12th was approaching a moderate depression over the southern Aleutians. The union of the two storm areas was of considerable moment, and on the 12th, 13th, 14th, and part of the 15th a great region extending from about the 170th meridian of east longitude to nearly the 160th meridian of west longitude, was swept by gales of forces up to 10, with pressures in some instances well below 29.00 inches. The lowest reported pressure was 28.67 inches observed on board the British S. S. *Empress of Canada*, at 7 p. m. of the 13th, in latitude 50° 37′ N., longitude 170° 26′ W. The next lowest pressure, 28.82 inches, and the highest wind force, 10, SSW. were recorded by the American S. S. *Hanley* early on the morning of the 14th, in 50° 03′ N., 170° 37′W.

Practically all observations of the storm during the last period were from north of the 45th parallel. The only gales reported from mid-ocean to the southward of this parallel were the following:

15th: By the American S. S. *Ethan Allen*, S. 7, in latitude 33° 50′ N., longitude 172° 35′ E.; lowest pressure, 29. 72 inches.

18th: By same vessel, SSW. 10, in 37° 55′ N., 170° 40′ W., lowest pressure, 29.88.

19th: By American S. S. *President Cleveland*, SSW. 7, in 31° 07′ N., 176° 04′ E.; lowest pressure, 29.81.

On June 20 a storm from China left the mainland. It was central on the 21st near the mouth of the Yellow Sea, with a minimum pressure of about 29.06 inches. Thence it moved northeastward, and by the 24th and 25th was causing gales over the steamship routes lying immediately to the southward of the western Aleutians. This cyclone was of considerable depth, for although it lost some energy in crossing Japan, it more than recovered what it had lost after entering the open ocean. The Japanese S. S. *Hawaii Maru*, Yokohama toward Victoria, observed the lowest pressure, 28.84 inches, and the highest wind force, 8, SSW. near latitude 46° 41′ N., longitude 169° 25′ E.

Toward the end of the month another middle-latitudes cyclone disturbed the weather in Asiatic waters, and on the 28th and 29th strong gales were experienced on the Pacific coast of Japan and to the eastward.

Over the eastern half of the Pacific, aside from the gales previously mentioned, only two areas with storm winds have been noted. From the 4th to the 6th, north to northwest gales, force 7 to 9, were experienced by the American S. S. *Eldridge* and the British S. S. *Empress of Australia* between the 49th and 52d parallels of north latitude and the 160th and 170th meridians of west longitude. No further report of June gales in northern waters east of the 160th meridian has been received.

The other area is that of the North American Tropics. One or more disturbances off the west coasts of Mexico and Central America emphasize the need for seamen in these waters to observe storm indications closely.

The first disturbance noted occurred on the 16th and 17th. Mr. C. A. McMullen, 2d officer of the U. S. A. T. *Edgemoor*, makes the following note of it:

> From Acapulco, Mexico, to Manzanilla Bay: Weather overcast, gloomy, with heavy rain squalls. Wind from a force of 4 increasing to force of 7, and shifting quickly from NE. to E., to SE. and *vice versa*. Heavy southwesterly swell. Rain squalls came up from direction opposite to that from which wind was blowing. This storm lasted throughout the passage, which time was 36 hours and 52 minutes. The lowest pressure (corrected) was 29.67 inches, in latitude 17° 37′ N., longitude 103° 05′ W.

This storm was also experienced on the 17th by the American S. S. *Cecil County*, San Pedro toward Balboa. Second Officer F. A. Davis remarks:

> Steady NW. wind during early morning, shifting to E., force 6, at 5 a. m., and increasing to a gale, force 9–10, at 9 a. m., with lowest pressure 29.63 inches, in 18° 16′ N., 104° 15′ W. (D. R.). After 9 wind shifted gradually to S., moderating in force, though frequent squalls continued throughout the day.

On June 19, while in San Jose Harbor, the American S. S. *San Juan* encountered an east-southeasterly gale, force 7, lowest pressure 29.65 inches. A gale of force 7, accompanied by only a slight reduction in pressure, was observed on the 24th, in 14° 55′ N., 94° 10′ W., by the British S. S. *Margaret Coughlan*.

Pressure continued to average normal or below normal over the eastern part of the ocean, as shown by observations at the island stations, this being the fourth month with an absence of pressure above normal. As was the case in the preceding month the deficiency occurred at Dutch Harbor and Midway Island. The mean monthly deviation in pressure at the latter station in June during the past 12 years has been between 0.04 and 0.05 inch; this year it was —0.07. The average for the month (29 days) based on p. m. observations was 30.02 inches. The highest pressure, 30.16, occurred on the 3d; the lowest, 29.92, on the 19th, 20th, and 21st. Pressure at Dutch Harbor, based on p. m. observations, averaged 29.77 inches for the month (29 days) as compared with a normal of 29.92. The mean deviation at this station in June is about 0.13 inch. The highest presure, 30.24, occurred on the 24th, the lowest, 28.90, on the 13th and 14th; absolute range 1.34 inches. The mean p. m. pressure at Honolulu was substantially normal at 30.04 inches. The highest pressure, 30.17, occurred on the 13th; the lowest, 29.90, on the 27th.

Fog during June was observed along the American coast region from 18° N. to Alaska, and over the entire width of the ocean along the northern routes. In the coast waters fog was reported as most frequent from the 35th parallel to the tip of Lower California, there being about 20 per cent of the days on which its occurrence was noted. Between the 180th meridian and Japan fog was encountered by trans-Pacific steamers on 65 per cent of the days.

FIVE TYPHOONS IN THE FAR EAST IN JUNE, 1923.

By Rev. JOSÉ CORONAS, S. J.

[Weather Bureau, Manila, P. I.]

The month of June has been very stormy in the Far East. No less than five typhoons have been noticed in our weather maps, two of them having been particularly severe and destructive in Yap (Western Carolines) and the Philippines, respectively.

The Samar and Leyte typhoon, June 3.—This typhoon was clearly shown by our weather maps in the afternoon of June 2 about 100 miles to the east of the southernmost part of Samar. Proper and timely warnings were sent immediately to the threatened regions of Samar and the northern part of Leyte. The center reached Samar close to Borongan (125° 26′ long. E., 11° 37′ lat. N.) shortly after midnight of June 2 to 3, barometric minimum registered there being as low as 729.52 mm. (28.72 inches). The typhoon inclined northward after crossing the southern part of Samar, moving NW. between Samar and Masbate. Once in southeastern Luzon, it traversed the Province of Camarines in a northerly direction, thus entering again the Pacific on the morning of June 4. In the Pacific it recurved further northeastward to the east of northern Luzon. We could not follow the typhoon after the 6th, and it is supposed that it filled up not far from 130° longitude E., and 20° latitude N. Very great damage was done to the Provinces of Samar and Leyte, but not so much to Masbate, Albay, and Camarines Provinces, as the typhoon seems to have decreased in intensity after crossing Samar. The town of Borongan in the eastern coast of Samar has been reported as practically swept by the winds, the sea waves, and the rain water rushing from the mountains.

The position of the center on the 2d to 6th was as follows:

June 2, 2 p. m., 127° 00′ long. E., 10° 55′ lat. N.
June 3, 6 a. m., 125° 00′ long. E., 11° 35′ lat. N.
June 3, 2 p. m., 124° 05′ long. E., 12° 05′ lat. N.
June 4, 6 a. m., 122° 50′ long. E., 13° 45′ lat. N.
June 5, 6 a. m., 124° 00′ long. E., 17° 30′ lat. N.
June 6, 6 a. m., 127° 15′ long. E., 19° 55′ lat. N.

The Yap typhoon, June 2, 1923.—At 2 p. m. of June 2, while our weather map showed a typhoon to the east of Samar, another one was shown to the SSE. of Yap, Western Carolines, in about 139° long. E., 8° lat. N. As it moved NNW. it passed practically over our station of Yap nearly before midnight of June 2, only two hours before the preceding typhoon reached the eastern coast of Samar, as stated above. The barometric minimum recorded at Yap was 737.82 mm. (29.05 inches) at 11:35 p. m., and the wind shifted from NW. to S., blowing with hurricane force for about five hours, and causing considerable damage to the Island. There were about two hours of relative calm from 10 p. m. to 12 midnight.

The typhoon was probably situated at 6 a. m. of the 3d and 4th at 122° 25′ long. E., 10° 40′ lat. N., and 124° 30′ long. E., 14° 30′ lat. N., respectively. Our weather maps did not show this typhoon any more after the 4th.

Two typhoons east of the Philippines, June 12 to 22.—The first of these typhoons appeared on the 12th to the SSE. of Guam between 145° and 149° longitude E., and in about 6° latitude N. It moved first westward, passing to the S. of Yap in the evening or night of the 13th; then it recurved N. and NE. on the 14th and 15th. The observations from Guam and Yap situated the center on the 16th in about 136° long. E., and 16° lat. N. It was impossible to follow it after the 16th.

The other typhoon was shown by our weather maps about 200 miles to the east of Samar, in the afternoon of the 16th. It moved NNW. on the 16th, N. on the 17th, NW. on the 18th, and N. again on the 19th and part of the 20th, when it passed close to the Meiacoshima group of Islands to the east of northern Formosa. On the 20th it inclined westward and reached the China coast between Shanghai and Formosa.

Typhoon in northern Luzon, June 29.—This typhoon appeared clearly on the 27th over 300 miles to the east of southern Luzon. It moved in a west-northwesterly direction and traversed the northern part of Luzon on June 29. Although the center passed over 100 miles to the north of Manila, strong winds and squalls caused some damage in the City. Considerable damage was done to the roads of Luzon north of Manila. The force of the winds near the center, however, was not much greater than in Manila. The typhoon inclined northward to the south of Hongkong and entered China a few miles to the west of Macao, where considerable damage was done according to cablegrams received in Manila on July 4.

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

ALFRED J. HENRY.

The current weather was exceptional in at least two respects, first, the rather long-continued spell of warm weather in the Middle Atlantic States, and thence northwest to the Lake region and Canada (see Chart III), and second, the heavy rains in the Arkansas River Valley in southern Kansas (see p. 329 of this REVIEW). In connection with the high temperatures in northeastern districts pilot-balloon observations during the continuance of the high temperatures seem to show an anticyclonic circulation at and above the 1-kilometer level; that is southerly winds over the Plains States, shifting to southwest over the Lake region and becoming northwest over the Middle Atlantic States. See also "Free Air Summary" p. 323 this REVIEW.

The usual details follow.

CYCLONES AND ANTICYCLONES.

By W. P. DAY.

Thirteen low-pressure areas were charted during June, the majority of which took shape over the Plateau and Rocky Mountain regions, where the air pressure is normally low at this season of the year. This persistent low pressure, especially in the far Southwest, in conjunction with the northward movement of the high-pressure belt over the ocean, is coincident with the cessation of the so-called South Pacific HIGHS, that is, high-pressure areas moving in from the Pacific in latitudes south of about 42°. In fact, this type is rarely noted between April and October, probably never in summer. It is also interesting to note that during practically the same period, few if any cyclonic storms pass inland from the Pacific south of latitude 50° with the possible exception of tropical disturbances on the coast of Lower

California. This becomes reasonable when one considers the great difference in normal pressure existing between the Pacific Ocean off California and the interior of California and the lower Colorado valley. All the minor disturbances of the summer months are lost on the slope of this great baric gradient.

Seven high-pressure areas were charted, three of the so-called North Pacific type and two each of the Alberta and Hudson Bay types.

FREE-AIR SUMMARY.

By L. T. SAMUELS, Meteorologist.

A noticeable feature of the mean free-air temperatures for the month was the difference in their variation from the normal over the various sections of the country. (See Table 1.) This characteristic was also pronounced at the surface as is shown by the Climatological Chart III. At most stations the departures did not change appreciably with increasing altitude. At Drexel, however, a consistent change from negative to positive occurred, becoming greatest at the highest level. This relation conforms closely with the increasing southerly component in the resultant wind found at that station from the surface to the highest altitude. (See Table 2.) During the heat waves which prevailed in the latter half of the month it was found that the free-air temperatures were, as a rule, proportionally high with respect to their normals, and in practically every case deep southerly winds prevailed from the surface to the highest levels.

Relative humidities averaged mostly in excess of their normals but the departures were practically all less than 10 per cent except in the highest levels where the observations are as yet too deficient in number to obtain reliable normals. The vapor pressures also averaged mostly above their normals for all stations except Ellendale.

In Table 2 are shown the resultant wind velocities and directions for the month and their normals. At Ellendale, Drexel, and Due West the southerly component exceeded the normal amount as did the resultant velocities at these stations. At the other stations, however, there was but little difference between the means and the normals.

At this season of the year, owing in part to the increase in the number of daylight hours in the higher latitudes, the horizontal temperature gradient from the equatorial to the polar regions becomes decidedly smaller than exists in winter. This condition results in an abatement of the strong upper winds characteristic of the latter season and instead these winds frequently continue extremely light to great heights. In fact, easterly winds are often then found to extend to the stratosphere. In general these conditions occur most frequently at the southern stations as is found this month. As an illustration of an exceptionally light wind extending from the surface to 9,000 meters above, the pilot-balloon observation of the 22d from Royal Center is cited. This velocity varied from practically calm to 3 m. p. s. but never exceeded this amount even to this height. At Broken Arrow on the same day the balloon was followed with two theodolites to a height of 9,600 meters and from that altitude by one theodolite to 20,300 meters. The wind was south from the surface to 10,000 meters where a shift to west and northwest occurred, remaining so to 15,000 meters, above which it backed steadily becoming southeast at the highest altitude. The velocity at the surface was 9 m. p. s. decreasing to practically calm at 10,000 meters where the shift occurred, then increasing sharply to 16 m. p. s. at 12,000 meters, above which it averaged about 10 m. p. s.

An unusually high two-theodolite observation was obtained at Groesbeck on the 6th when the balloon was followed for 67 minutes reaching a height of 13,000 meters. Strong winds of 30 m. p. s. from the northwest were found at this high altitude.

The morning kite flight at Broken Arrow on the 6th was completed just as a thunderstorm broke at that station. The storm lasted about one hour and a second kite flight was made immediately after the rain stopped. Both flights attained slightly more than 3,500 meters' altitude and are, therefore, of special interest since they show the free-air conditions just preceding and following a typical convection thunderstorm. The general wind drift at the surface was from the south but during the storm this changed to northerly becoming southerly again immediately after the storm. The temperature lapse-rate off the surface during the morning nearly equalled the adiabatic rate for dry air, indicating conditions favorable for convection and supporting thunderstorm development. The winds above 1,000 meters had a greater west component after the storm than they had before and were of a slightly higher velocity. The other elements such as temperature, relative humidity and vapor pressure resumed practically their former state. There was discernible, however, in the second flight a consistently higher temperature to 2,500 meters and a correspondingly lower relative humidity. The small change in the free-air conditions would be expected, since the thunderstorm, originating in some other locality, was merely carried over Broken Arrow by the upper wind and once having passed, the elements would quickly resume their former state.

The following pertinent note by the official in charge of the Drexel station relative to a series of kite flights made on the 20th and 21st is of interest in connection with flights made during thunderstorm conditions:

> The weather was generally cloudy and at times threatening during the daylight hours and for the most part clear in the night. Lines of showers passed the station at intervals to the east and the west moving from south to north. Eventually light showers passed over the station during the last flight, thunder began immediately after the flight, and a light drizzling rain set in a few hours later. The showers evidently were the development of clouds of a convectional nature as a characteristic of the weather throughout the week has been cloudy and threatening weather by day and generally clear weather at night.

A decidedly large lapse rate as well as generally high humidity was apparent throughout the entire series. The general wind direction during the series remained mostly south from the surface to the highest levels reached (3,500 meters). The velocities aloft showed an appreciable increase as the series progressed. The temperature above the surface showed practically no change during the series and the moisture content varied with the changes in cloudiness.

The following from Broken Arrow appearing on the kite flight of the 6th is of interest:

> Large oil fire at West Tulsa; smoke topped by cumulus cloud. Fire started by thunderstorm during morning.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during June, 1923.*

TEMPERATURE (°C.).

Altitude, m. s. l. (meters).	Broken Arrow, Okla. (233 meters.)		Drexel, Nebr. (396 meters.)		Due West, S. C. (217 meters.)		Ellendale, N. Dak. (444 meters.)		Groesbeck, Tex. (141 meters.)		Royal Center, Ind. (225 meters.)	
	Mean.	Departure from 5-year mean.	Mean.	Departure from 8-year mean.	Mean.	Departure from 3-year mean.	Mean.	Departure from 6-year mean.	Mean.	Departure from 5-year mean.	Mean.	Departure from 5-year mean.
Surface..	24.8	+0.2	20.7	−0.9	27.1	+0.5	19.8	0.0	26.8	+1.0	23.4	−0.2
250......	24.7	+0.2	......	......	26.7	+0.5	......	......	25.7	+0.8	23.1	−0.2
500......	22.9	+0.4	20.0	−0.9	23.9	+0.5	19.6	+0.1	23.4	+0.4	20.3	−0.3
750......	21.3	+0.5	18.6	−0.7	21.7	+0.2	18.1	+0.1	21.8	+0.3	18.0	−0.6
1,000.....	19.9	+0.5	17.7	−0.3	19.8	−0.1	16.4	−0.3	20.5	+0.3	16.0	−1.0
1,250.....	18.7	+0.7	16.5	−0.1	17.9	−0.4	15.0	−0.5	19.3	+0.4	14.3	−1.2
1,500.....	17.4	+0.9	15.2	−0.1	16.0	−0.6	13.9	−0.4	18.3	+0.7	12.9	−1.1
2,000.....	14.5	+1.0	12.8	+0.3	12.5	−0.8	11.1	−0.3	16.1	+1.0	10.5	−0.8
2,500.....	11.4	+0.7	10.5	+1.0	9.2	−0.9	8.5	0.0	13.7	+1.2	8.1	−0.4
3,000.....	8.4	+0.7	7.7	+1.2	6.5	−0.7	5.9	+0.2	11.2	+1.2	5.0	−0.7
3,500.....	5.3	+0.7	4.7	+1.5	3.8	−0.3	3.0	+0.2	8.4	+1.1	2.1	−0.9
4,000.....	2.2	+0.6	1.8	+1.9	1.6	+0.3	−0.2	−0.1	5.6	+0.9	−0.9	−1.5
4,500.....	−2.0	−0.4	−1.0	+2.0	−1.0	−0.1	−3.2	+0.1	......	......	−4.1	−2.1
5,000.....	......	......	−3.8	+2.6	......	......	−6.0	+0.1	......	......	......	......

RELATIVE HUMIDITY (%).

Altitude, m. s. l. (meters).	Broken Arrow Mean.	Departure	Drexel Mean.	Departure	Due West Mean.	Departure	Ellendale Mean.	Departure	Groesbeck Mean.	Departure	Royal Center Mean.	Departure
Surface..	77	+3	80	+11	60	−2	69	−3	71	−3	66	+4
250......	77	+3	......	......	60	−3	......	......	74	−1	67	+5
500......	77	+3	78	+10	64	−2	68	−3	79	+3	71	+7
750......	77	+3	75	+9	67	0	67	−2	79	+4	74	+8
1,000.....	76	+3	72	+7	69	+1	69	+1	76	+4	74	+7
1,250.....	72	0	72	+7	70	+2	69	+3	72	+3	74	+7
1,500.....	68	−2	72	+9	71	+3	64	0	67	+1	71	+5
2,000.....	66	−1	69	+9	75	+6	61	−1	59	−1	63	+1
2,500.....	64	+5	59	+1	78	+7	54	−5	54	−2	49	−3
3,000.....	60	+5	57	0	73	+5	46	−8	53	+2	48	0
3,500.....	60	+6	56	−1	67	+2	43	−8	52	+3	45	+4
4,000.....	58	+7	51	−5	57	+3	43	−6	52	+4	48	+19
4,500.....	72	+23	52	−1	58	+16	34	−17	......	......	52	+25
5,000.....	......	......	58	+2	......	......	35	−16	......	......	......	......

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressure during June, 1923*—Continued.

VAPOR PRESSURE (mb.).

Altitude, m. s. l. (meters).	Broken Arrow, Okla. (233 meters.)		Drexel, Nebr. (396 meters.)		Due West, S. C. (217 meters.)		Ellendale, N. Dak. (444 meters.)		Groesbeck, Tex. (141 meters.)		Royal Center, Ind. (225 meters.)	
	Mean.	Departure from 5-year mean.	Mean.	Departure from 8-year mean.	Mean.	Departure from 3-year mean.	Mean.	Departure from 6-year mean.	Mean.	Departure from 5-year mean.	Mean.	Departure from 5-year mean.
Surface..	24.28	+1.27	19.87	+1.82	21.22	+0.16	16.03	−0.78	24.69	+0.31	19.25	+1.01
250......	24.11	+1.32	......	......	20.92	+0.19	......	......	24.12	+0.65	19.10	+1.08
500......	21.66	+1.39	18.57	+1.72	18.80	+0.29	15.68	−0.62	22.58	+1.15	17.20	+1.36
750......	19.44	+1.22	16.11	+1.37	17.27	+0.41	14.20	−0.10	20.58	+1.18	15.60	+1.14
1,000.....	17.52	+0.98	14.52	+1.07	15.84	+0.38	13.18	+0.33	18.25	+1.05	14.06	+0.77
1,250.....	15.06	+0.24	13.48	+1.26	14.44	+0.34	12.10	+0.57	16.10	+0.84	12.50	+0.35
1,500.....	13.30	+0.09	12.37	+1.51	13.09	+0.33	10.19	−0.02	14.01	+0.67	10.86	+0.01
2,000.....	10.67	+0.39	10.11	+1.47	10.91	+0.44	7.97	−0.26	10.90	+0.52	8.05	−0.11
2,500.....	8.28	+0.85	7.35	+0.49	8.99	+0.47	6.13	−0.51	8.58	+0.32	5.41	−0.02
3,000.....	6.20	+0.76	5.77	+0.21	6.98	+0.35	4.00	−0.98	7.27	+0.73	4.12	+0.30
3,500.....	4.94	+0.63	4.43	−0.05	5.22	+0.21	3.16	−0.86	6.07	+0.73	2.94	+0.62
4,000.....	3.89	+0.53	3.40	−0.23	3.66	+0.40	2.52	−0.80	4.99	+0.56	2.68	+1.91
4,500.....	3.61	+0.96	2.96	+0.19	3.12	+1.04	1.35	−1.42	......	......	2.54	+2.36
5,000.....	......	......	2.78	+0.55	......	......	1.26	−1.41	......	......	......	......

TABLE 2.—*Free-air resultant winds (m. p. s.) during June, 1923.*

Altitude, m. s. l.	Broken Arrow, Okla. (233 meters.)				Drexel, Nebr. (396 meters.)				Due West, S. C. (217 meters.)				Ellendale, N. Dak. (444 meters.)				Groesbeck, Tex. (141 meters.)				Royal Center, Ind. (225 meters.)			
	Mean.		5-year mean.		Mean.		8-year mean.		Mean.		3-year mean.		Mean.		6-year mean.		Mean.		5-year mean.		Mean.		5-year mean.	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
(Meters).																								
Surface.....	S. 2° W.	4.2	S. 3° W.	3.8	S. 13° E.	3.3	S. 4° W.	1.7	S. 48° W.	2.4	S. 77° W.	0.8	S. 9° E.	1.7	S. 22° E.	0.4	S. 22° E.	3.9	S. 17° E.	2.9	S. 58° W.	2.6	S. 52° W.	1.3
250........	S. 3° W.	4.3	S. 4° W.	3.9	....	...	....	...	S. 48° W.	2.4	S. 75° W.	0.9	....	...	....	...	S. 20° E.	4.8	S. 16° E.	3.5	S. 57° W.	2.6	S. 51° W.	1.3
500........	S. 8° W.	5.9	S. 11° W.	5.2	S. 7° E.	5.1	S. 3° W.	2.3	S. 48° W.	2.8	S. 76° W.	1.3	S. 10° E.	1.9	S. 11° E.	0.6	S. 12° E.	6.9	S. 7° E.	4.8	S. 54° W.	3.8	S. 46° W.	2.2
750........	S. 11° W.	6.6	S. 14° W.	5.9	S. 4° W.	8.3	S. 15° W.	3.5	S. 47° W.	3.4	S. 71° W.	2.0	S. 2° E.	3.3	S. 4° E.	1.3	S. 4° E.	7.2	S. 3° E.	5.2	S. 57° W.	5.0	S. 53° W.	2.9
1,000.......	S. 18° W.	6.5	S. 20° W.	6.1	S. 15° W.	8.5	S. 29° W.	4.1	S. 51° W.	3.6	S. 71° W.	1.9	S. 13° W.	4.1	S. 17° W.	1.8	S. 4° W.	7.1	S. 1° W.	5.5	S. 57° W.	5.7	S. 66° W.	3.4
1,250.......	S. 26° W.	6.2	S. 24° W.	6.1	S. 20° W.	8.8	S. 40° W.	4.3	S. 55° W.	4.4	S. 72° W.	2.3	S. 17° W.	4.4	S. 39° W.	2.2	S. 5° W.	7.6	S. 4° W.	6.0	S. 65° W.	5.5	S. 75° W.	3.7
1,500.......	S. 29° W.	5.9	S. 27° W.	6.2	S. 32° W.	8.6	S. 52° W.	5.0	S. 67° W.	5.4	S. 79° W.	3.2	S. 23° W.	4.6	S. 43° W.	2.6	S. 12° W.	7.2	S. 5° W.	5.4	S. 60° W.	5.9	S. 84° W.	4.1
2,000.......	S. 35° W.	5.7	S. 33° W.	6.3	S. 35° W.	8.6	S. 59° W.	6.0	S. 80° W.	7.3	S. 85° W.	5.1	S. 30° W.	4.5	S. 56° W.	3.5	S. 17° W.	6.9	S. 7° W.	5.1	S. 70° W.	7.7	S. 84° W.	6.2
2,500.......	S. 38° W.	5.7	S. 32° W.	6.4	S. 41° W.	10.5	S. 67° W.	7.1	S. 79° W.	6.1	S. 86° W.	5.1	S. 49° W.	5.6	S. 67° W.	5.3	S. 18° W.	6.8	S. 12° W.	5.1	S. 70° W.	8.6	S. 83° W.	8.2
3,000.......	S. 42° W.	6.5	S. 27° W.	6.4	S. 43° W.	10.8	S. 72° W.	8.5	S. 81° W.	7.8	S. 85° W.	6.8	S. 72° W.	7.6	S. 76° W.	7.3	S. 10° W.	6.3	S. 14° W.	5.4	S. 71° W.	8.8	S. 86° W.	10.2
3,500.......	S. 48° W.	8.2	S. 34° W.	7.8	S. 29° W.	11.3	S. 74° W.	9.1	S. 63° W.	9.7	S. 66° W.	7.8	S. 77° W.	8.7	S. 81° W.	8.4	S. 3° W.	6.3	S. 8° W.	6.4	S. 77° W.	8.8	S. 88° W.	12.3
4,000.......	S. 30° W.	9.8	S. 33° W.	8.1	S. 35° W.	8.4	N. 87° W.	8.2	S. 66° W.	11.9	S. 69° W.	10.1	N. 84° W.	12.3	N. 85° W.	10.5	S. 17° W.	7.6	S. 2° W.	7.2	N. 80° W.	4.5	W.	13.0
4,500.......	S. 32° W.	10.5	S. 46° W.	6.5	S. 16° W.	7.4	N. 77° W.	8.4	W.	17.7	N. 72° W.	12.2	S. 61° W.	9.6	N. 80° W.	12.1	S. 7° W.	7.2	S. 16° E.	9.3	N. 67° W.	11.3	S. 77° W.	7.1
5,000.......	W.	13.6	W.	13.6	N. 45° W.	18.1	N. 52° W.	18.8	....	...	....	...	N. 23° W.	15.9	N. 64° W.	16.2	....	...	....	...	N. 22° W.	23.7	N. 22° W.	23.7

THE WEATHER ELEMENTS.

By P. C. DAY, Meteorologist, in Charge of Division.

PRESSURE AND WINDS.

The atmospheric circulation during June, as in the preceding month, and as may be expected in the warmer months of the year, was without sudden and important variations, and cyclonic and anticyclonic activity were both at a low ebb during much of the month. While the pressure was frequently low over the Mountain and Plateau districts, the cyclonic disturbances originating there were mainly unable to advance far to the eastward on account of rather persistent, though moderate, anticyclonic conditions over the central valleys and southeastern districts.

One of the most important cyclones of the month, though not well defined, but accompanied by widespread precipitation, moved slowly from the western mountain regions eastward to the Atlantic coast during the middle part of the first decade. Heavy falls of rain accompanied this storm locally in the central valleys and parts of the East, though the Southern States had usually only scattered showers. As this disturbance was passing off the North Atlantic coast another rather important cyclone developed over the Southwest, and moved slowly eastward, reaching the Middle and South Atlantic coasts by the 13th. This was likewise attended by widespread precipitation, though the notably heavy falls were confined mainly to the districts from the central Plains eastward. At Wichita, Kans., a 24-hour fall of nearly

7 inches was measured on the morning of the 9th, and Dallas, Tex., had nearly 5 inches on the 10th and 11th, while farther eastward Macon, Ga., reported nearly 7 inches on the same dates.

During the middle period of the month the pressure distribution favored local thunderstorms in widely separated districts. These were rather general over the Missouri Valley and Plains States on the 18th and 19th, and again in the Rocky Mountains and portions of the Great Plains on the 20th to 22d.

An important cyclone from the precipitation standpoint, though the pressure variations were mainly small, moved from the central valleys on the morning of the 27th to the Atlantic coast districts by the 29th. This brought some heavy rains in southern Georgia, northern Florida, and in the many sections of the Ohio and Mississippi Valleys.

The average pressure for the month was mainly below normal from the Great Plains westward and over the more eastern districts of both Canada and the United States. Over a narrow area in the Mississippi Valley, extending from the Gulf to the Canadian boundary, and along the eastern slope of the Rocky Mountains, the average pressure was generally slightly above normal.

The June averages of pressure were mainly less than those for the preceding month, as is usually the case over most northern and western districts, but from the middle and southern Plains eastward the June averages, which usually are higher than those for May, were distinctly so during this month.

High winds frequently accompanied the numerous thunderstorms as may be expected during heated periods, and storms of a tornadic character were reported from several localities, the full details of which appear in the table at the end of this section or in special reports elsewhere in this issue.

The prevailing wind systems of the various sections were not strongly developed, owing to the moderately even distribution of pressure.

TEMPERATURE.

The month opened unseasonably cool over the far West with temperatures below freezing and injurious frosts on the 1st and 2d, over elevated portions of Arizona, Nevada, and Utah. At the same time moderate warmth was the rule over the districts from the Rocky Mountains eastward. By the middle of the first decade temperatures had generally risen to normal in the far West, and they were distinctly above to the eastward.

During the week ended the 12th a rather widespread area extending from southern California northeastward to the Great Lakes and New England had temperatures moderately lower than normal, while in the far Northwest, and from Texas eastward and northeastward to the middle Atlantic coast the averages were above normal. No unusual extremes of temperature were noted during this period.

The week ending June 19 had some sharp temperature changes in the far West, notably on the 13th when freezing weather was reported from Nevada, and by the following morning unseasonably cool weather had overspread much of the country from the Rocky Mountains westward. This condition, in somewhat modified form, persisted during most of the week in the western districts and the average temperatures for that period, as a whole, ranged from 3 to 12 degrees below normal. To the eastward of the Rocky Mountains this week was on the whole warm in the Great Plains, upper Mississippi Valley, and Great Lakes region, and particularly so over the Dakotas and eastern Montana, where the averages ranged from 6 to 9 degrees above normal. Over the States south of the Ohio and east of the Mississippi, as well as those of the Atlantic coast, except Florida, this week was mainly cooler than normal.

The following week, 18th to 26th, continued cool nearly throughout in the districts to westward of the Rocky Mountains, the lowest temperature ever observed in June being reported from Phoenix, Ariz., on the 21st. To the eastward of the Rockies, however, the week was mainly warm, particularly in the eastern Great Plains, central valleys, and thence to the Middle Atlantic States. In these districts the week was almost continuously warmer and in many sections had longer periods of intense heat than ever before known in June. Many cases of death from heat prostration occurred and farm animals in the fields suffered greatly. In portions of these districts the highest temperatures ever observed in June were recorded, while, as stated above, the lowest in June were being experienced at points in Arizona.

A change to cooler weather set in over the upper Missouri Valley about the middle of the last decade and the last few days of the month were moderately cool over practically all portions of the country east of the Rocky Mountains. In the far West warm weather set in about the 27th and continued at the end of the month.

For the month as a whole the average temperature was above normal over all districts east of the Rocky Mountains save from the lower Mississippi Valley eastward, where moderately cool weather continued as had been the case since February of the present year over most districts east of the Rocky Mountains until the present month. In portions of the Middle Atlantic States and thence to the Great Lakes and upper Mississippi Valley the month was among the warmest of record for June, and in portions of Pennsylvania, New Jersey, and Maryland it was the warmest June of record. To the westward of the Rockies, save over a small area in the far Northwest, the month was nearly constantly cool and in portions of Arizona and California it was the coolest June of record.

Maximum temperatures of 100°, or somewhat higher, were observed in some portions of all the States except in the middle Gulf and near the Lake Superior region.

The highest temperatures were recorded about the 7th and 8th in portions of the east Gulf States; about the 20th to 27th in most other districts east of the Rocky Mountains and near the end of the month in the far West.

The lowest temperatures of the month were reported in the first few days in many portions of the Plateau and Pacific Coast States; about the 6th to 9th in the Dakotas and parts of surrounding States; from the 12th to 15th in the northeastern districts and parts of the far Northwest; on the 17th and 21st in Arizona and generally on the 29th to 30th in the great central valleys and Southeastern States. The readings on the last-mentioned dates were the lowest, or among the lowest, ever observed so late in June in many sections of the middle Mississippi and lower Ohio Valleys and the Southern States.

PRECIPITATION.

Over the districts where rainfall in generous amounts is to be expected in June, there was on the whole no great deficiency over large areas, and the distribution was generally such as to favor agricultural and other interests, save in a few localities.

There was entirely too much rain for current needs over considerable areas in Kansas, Oklahoma, and northern Texas, and great damage to crops and other interests resulted, particularly in Oklahoma. In portions of the Middle and East Gulf States there was likewise a marked excess in precipitation, which, following the heavy rains of the preceding month, caused material loss or damage to crops.

On the other hand, there was a marked deficiency in precipitation along the immediate Atlantic coast from Florida to Pennsylvania. In portions of this area, particularly in eastern Pennsylvania, the month had the least precipitation for June in 50 years.

In general, precipitation was materially above normal over portions of the middle Gulf States; in the Great Plains, and eastern slopes of the Rocky Mountains, where at points in northern Texas the precipitation was the greatest ever reported in June; and in the Northern Plateau, where, in some localities, notably in northern Nevada, the total fall for the month was likewise the greatest for June of record. In the western Canadian Provinces, particularly those immediately to northward of Montana, the precipitation for the month was unusually heavy, some stations reporting nearly 5 inches in excess of the normal. In the west Gulf States there was a marked deficiency, and in the Great Lakes region and upper Mississippi Valley a moderate deficiency existed.

As is usual in summer, the precipitation was mostly the result of thunderstorms, and on account of their frequent local nature the monthly precipitation varied greatly within narrow limits. Some of these variations by States are extraordinarily large, notably in Alabama the monthly precipitation ranged from 14.07 to 1.23 inches; Texas, from 11.81 to 0.00; New Mexico, from 12.31 to 0.00; and North Dakota, from 10.27 to 0.91.

SNOWFALL.

In the high mountains of California snow fell on the 15th and 16th; Tamarack, elevation 8,000 feet, reporting 9 inches, and Lake Tahoe, elevation 6,230 feet, 4 inches; and more or less snow was reported also from the high ranges of Nevada, Utah, Oregon, and in the main ranges of the Rockies.

On account of moderately cool and frequently cloudy weather, snow melting was not so rapid as usual; there was, however, plenty of water for irrigation purposes in California as well as in other districts where a supply of water from melting snow is expected so late in the season.

RELATIVE HUMIDITY.

Atmospheric moisture as expressed by the relative humidity was above normal over the greater part of the country, the excesses being most pronounced in the middle Plains, lower Missouri Valley, and locally in the Central Gulf States and the far West.

Along the Atlantic coast from Georgia to New England and generally over the upper Ohio drainage area and the Great Lakes region the relative humidity was well below the normal, and portions of the Rocky Mountain and Plateau States likewise has less than normal.

SEVERE LOCAL STORMS, JUNE, 1923.

[The table herewith contains such data as have been received concerning several local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau.]

Place.	Date.	Time.	Width of path (yards).	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
Cheyenne, Wyo	2	P. m.	3 to 14		$200	2 tornadoes	Barn and many fences damaged	Official, U. S. Weather Bureau.
Carlisle, Pa	3					Thunderstorm	Trees and poles blown down. Some injury to crops by hail.	Do.
Fort Wayne, Ind	5	P. m.		1		Electrical and wind.	Between 600 and 800 telephones out of commission. Power plants damaged.	Do.
Hartford, Conn	6	...do.				Thunderstorm	Telephone service crippled; light and power lines damaged and a number of buildings struck by lightning. Tobacco crop injured by hail.	Do.
Eastern Washington	6	...do.				Electrical and rain.	Poles blown down, lighting service cut off; telephone service crippled.	Spokesman Review (Spokane, Wash.).
New York, N. Y., and vicinity.	6	4 p. m.		1		Wind	Trees uprooted and buildings damaged. Many cellars flooded.	Times (New York).
Hoxie and Walnut Ridge, Ark.	6				1,500	...do.	Considerable property damage	Official, U. S. Weather Bureau.
Roswell, N. Mex	8	P. m.			10,000	Tornado	Several houses, barns, and outbuildings destroyed.	Do.
Macon, Ga	10	...do.				Wind and rain	Damage to merchandise, dwellings and streets estimated at thousands of dollars.	Do.
South central Kansas	14	...do.		1		...do.	Town of Peck devastated, other villages damaged. Several persons injured.	Wichita Eagle (Kans.).
San Juan Basin, Colo	16-17					Wind and sand	Houses and barns unroofed; trees uprooted and highways blocked.	Post (Denver, Colo.).
Fond Du Lac, Wis	18				8,000	Wind and electrical.	Many tents destroyed and buildings at fair grounds damaged.	Wisconsin State Journal (Madison, Wis.).
Tallula, Ill	18	P. m.			50,000	Wind and hail	Heavy damage to buildings and crops	Official, U. S. Weather Bureau.
Pittsburgh, Pa	19	2 p. m.				Thunderstorm	Oil tank struck by lightning, causing disastrous fire: 14 men injured and 11 families driven from homes.	Do.
Moorhead, Minn	22				10,000	Wind and rain	Trees, telephone poles, and shop windows damaged.	Do.
Clarksville, Tenn	22					Thunderstorm	General damage estimated at several thousand dollars.	Do.
Lovell, Wyo	22		1,760		5,000	Tornado	Details of damage not reported. Path 7 miles long.	Do.
Clymer, Pa	23					Wind	Six houses damaged	Do.
Washington and Frederick Counties, Maryland.	23					Thunderstorms	A number of dwellings and barns damaged and trees uprooted.	Do.
New York State (greater portion of).	24				255,000	...do.	Heavy damage; principally to crops	Do.
Adams County, N. Dak	24			7		Tornado	Trees and buildings damaged and wires tangled.	Daily News (St. Paul, Minn.)
Springfield, Mass. (vicinity of).	24					Electrical and hail.	Considerable minor damage	Official, U. S. Weather Bureau.
Rochester, N. Y	25	P. m.				Wind	Considerable damage to trees and wires	Do.
Niagara County, N. Y	25					Thunderstorms	Orchards injured and forest trees blown down	Do.
Southern Wisconsin	25	P. m.		1	300,000	...do.	Heavy property damage	Do.

Severe local storms, June, 1923—Continued.

[The table herewith contains such data as have been received concerning several local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau.]

Place.	Date.	Time.	Width of path (yards).	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
Camden, S. C.	25				3,000	Electrical	Barn destroyed and valuable horse killed	Official, U. S. Weather Bureau.
Greenwood, S. C. (near)	25				2,500	do	Two barns and contents destroyed	Do.
Tobacco section of Connecticut.	26				100,000	Electrical and hail.	Tobacco and tobacco barns heavily damaged	Do.
Oakland, Md. (2½ miles south of).	26					Wind	A house and barn blown down, and several children injured.	Do.
New York City and vicinity	26			3		Wind and electrical.	Some property damage and several persons injured.	Tribune (N. Y.).
Southwestern and central Iowa.	27			1		Wind and rain	Considerable property damage and crops severely injured.	Official, U. S. Weather Bureau.
Evansville, Ind	27					do	Crops damaged and wires, trees, signs, and chimneys blown down.	Do.
Springfield, Mo	27					Wind	Minor damage done	Do.
Jonesboro, Ark	27				7,000	Tornado	Considerable property damage	Do.
Brownsville, Tenn	27	P. m				Thunderstorm	Several buildings unroofed, plate windows broken, light and telephone poles and trees blown down.	Do.
Ridgely, Tenn	28			2		do	Much property damage	Do.
Rapid City, S. Dak. (2 to 3 miles west of).	29	P. m	1,760 to 3,520.			Hail	Heavy crop damage	Do.
Dodge City, Kans	29				600,000	Wind and hail	Considerable damage, principally by hail	Do.

STORMS AND WEATHER WARNINGS.

By EDWARD H. BOWIE, Supervising Forecaster.

WASHINGTON FORECAST DISTRICT.

From a forecasting standpoint the month was relatively quiet in the Washington Forecast District. No storms of marked severity crossed the district during the month and the advisory information issued for the coastal waters was in connection with the occurrence of squalls attending thunderstorms. No regular storm warnings were issued during the month, although on the evening of the 25th announcement was made for the East Gulf region concerning the presence of a disturbance of slight intensity off the Louisiana coast. This disturbance advanced east-northeastward during the night of the 25th and during the 26th it passed off the South Atlantic coast in the vicinity of Charleston. It was attended by excessive rains over a narrow belt extending from the Louisiana coast eastward to the Atlantic coast and by winds of more than 40 miles an hour in the vicinity of Pensacola, Fla.

On June 8 small-craft warnings were displayed on the Atlantic coast at and north of the Virginia Capes, in expectation of fresh and strong northwest winds during the following afternoon and night of that day; and on the 26th small-craft warnings were again displayed over the same coastal region in expectation of the occurrence of squalls during the afternoon and night of the 26th. The squalls forecast on the 26th occurred quite generally, the severest taking place in the vicinity of New York, where the wind for a short period equalled 60 miles an hour.

Hot waves were the notable feature of the weather during the month, the beginnings and endings of which were successfully forecast. In respect to warm weather, the month was notable, as for example at Washington, D. C., the month gave a greater number of days with maximum temperature 90°, or higher, than ever before recorded at this station in June. It also established for Washington a new June record for consecutive days, 8 in number, with temperature 90°, or higher.

No frost warnings were necessary during the month, although on several days the temperature in the cranberry bogs of New Jersey approached very close to the freezing point.

CHICAGO FORECAST DISTRICT.

No general warnings were necessary in the Chicago Forecast District during the month. There was great variation in temperature, rather cool during the first part, followed by an abnormally warm period, with another period of unseasonably cool weather in the closing days of the month.

Special advices in regard to weather conditions were issued from time to time, and occasionally when the weather map justified, a forecast was made for several days in advance.

The coming of the great heat wave was anticipated in a statement issued on Tuesday, June 12, as follows: "The temperature will rise in the Plains States to-night and in the Middle States Wednesday, and there are now indications of the development of a heat wave in this region before the close of the present week." This was followed on the following day by an additional statement, "The temperature will gradually rise throughout the Middle States, resulting in a warm wave before the end of the week, as indicated in Tuesday's weather bulletin." By the following Monday, June 18, the heat wave had become general over the central portions of the country, the first pronounced heat wave of the season. Shippers of perishable goods were advised of the coming of this heat wave, and, doubtless, important service was rendered by the Bureau at this time.—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT.

The weather during June, 1923, did not depart greatly from the conditions that are usual for the month. No storm warnings were issued or required; but threatening conditions in the extreme western portion of the Gulf of Mexico on the 8th justified the display of small-craft warnings issued for the Texas coast on that data.—*R. A. Dyke.*

DENVER FORECAST DISTRICT.

The month was unusually dry and cool in the greater part of the district. The prevalence of high pressure in the Eastern States during the greater part of the month exerted a marked influence on the movement of LOWS in western districts.

Warnings of local frost were issued for Utah, western Colorado and the mountain districts of New Mexico on the 1st, as relatively high pressure prevailed on the western slope attended by abnormally low temperature. While frost temperatures occurred in places, with freezing weather in northeastern Arizona, a considerable rise in temperature prevented further serious damage. Frost warnings for western Utah were issued on the 13th, when the pressure was low in Rocky Mountain districts and an anticyclonic area was advancing eastward from the middle Pacific. Frost temperatures occurred in localities. On the 22d advices of possibly local frost were issued for western Utah. The center of an area of low pressure occupied the middle Rocky Mountain section, with cooler weather in the Plateau region, frost in Nevada, and rising pressure on the California coast. The rapid development of an area of low pressure of considerable intensity in Nevada was attended by rising temperature.—*Frederick W. Brist.*

SAN FRANCISCO FORECAST DISTRICT.

During the month of June the high-pressure area over the eastern portion of the North Pacific Ocean was slower than usual in gaining strength and stability; consequently it did not impinge on the coast to any great extent till near the end of the month. The result was the formation of irregular-shaped troughs of low pressure over the Rocky Mountain and Pacific States that caused protracted spells of cool and unsettled weather in the San Francisco Forecast District. The passage eastward of these trough-shaped low-pressure areas was more or less checked by the presence of persistent high-pressure areas over the Mississippi Valley and the Atlantic States. This type of weather while difficult to predict was of inestimable benefit to the grain crops, and it did much to prevent the spread of forest fires, which sometimes are numerous at this time of the year, especially in the southern portion of the district.

The only warning issued was for light-to-heavy frost in exposed places in Idaho on the 16th inst. No storm warnings were issued nor were any necessary.—*E. A. Beals.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

The only great flood of the month occurred in the Arkansas River from the vicinity of Hutchinson, Kans., to the mouth of the river. To the westward, the river was only in moderate flood, and flood stages were not reached except at Fort Lyon, Colo., where the river was above the flood stage of 6 feet on June 17, with a crest stage of 10 feet at 8 p. m.

It is evident that the major portion of this rise came from the Purgatoire River, at Higbee, Colo., on that river, reported the washing out of the river gage on June 17, at a stage of 10 feet, or 6 feet above the flood stage, with the river still rising. Flood warnings for the Arkansas River from Fort Lyon to the Kansas line were issued at once, and no serious damage was reported, as the excess water was apparently diverted to the irrigation canals. Other streams in northeastern Colorado were also in flood.

The following account of the flood from Hutchinson, Kans., eastward was summarized from the detailed reports of Messrs. S. P. Peterson, T. G. Shipman, H. S. Cole, and J. P. Slaughter in charge of the river districts—Wichita, Kans., Fort Smith, Ark., Little Rock, Ark., and and Oklahoma City, Okla., respectively. The rainfall responsible for the floods is shown in the following table:

Rainfall, May 21 to June 17, inclusive, 1923.

Station.	River.	Total for 28 days.
		Inches.
Macksville, Kans	Arkansas	9.31
Great Bend, Kans	do	9.90
Hutchinson, Kans	do	11.01
Medora, Kans	do	12.73
McPherson, Kans	do	11.04
Hesston, Kans	Little Arkansas	11.93
Newton, Kans	do	12.69
Sedgwick, Kans	do	13.13
Wichita, Kans	Arkansas	18.36
Ralston, Okla	do	6.14
Tulsa, Okla	do	11.35
Webbers Falls, Okla	do	8.52
Emporia, Kans	Cottonwood	12.13
Neosho Rapids, Kans	Neosho	10.06
LeRoy, Kans	do	9.60
Iola, Kans	do	8.69
Oswego, Kans	do	7.97
Wyandotte, Okla	do	12.27
Okay, Okla	Verdigris	7.13
Fort Gibson, Okla	Neosho	6.96
Camargo, Okla	North Fork Canadian	7.97
Union City, Okla	do	7.36
Woodward, Okla	do	9.53
Canton, Okla	do	8.22
Reno Junction, Okla	do	5.47
Oklahoma City, Okla	do	7.21
Calvin, Okla	Canadian	8.80
Fort Smith, Ark	Arkansas	8.65
Dardanelle, Ark	do	8.24
Danville, Ark	Petit Jean	8.25
Little Rock, Ark	Arkansas	5.19
Calico Rock, Ark	White	8.98
Batesville, Ark	do	8.91
Newport, Ark	do	12.56
Pine Bluff, Ark	Arkansas	6.07
Black Rock, Ark	Black	7.71
Patterson, Ark	Cache	14.66
Georgetown, Ark	White	11.95
Clarendon, Ark	do	7.87

It will be seen from the above table that there was a period of almost four weeks of continuous rains over eastern Kansas, Oklahoma, and Arkansas. From May 21 to 24, inclusive, the rains were heavy. On June 9, they were excessive over Kansas and Oklahoma, and on June 10 over Arkansas. The mean rainfall for the 28 days over the three sections mentioned was 9.60 inches, from two to more than three times the normal amount for the season, with the greatest excess over southeastern Kansas.

Hutchinson, Kans., to Wichita, Kans.—The area covered by the heavy rains was about 45 miles in length, 60 miles in width over the upper portion, and 40 miles over the middle portion, converging to about 10 miles at the extreme lower end. The flooded area was about 40 miles in width at Hutchinson, Medora, and McPherson, Kans., and became extensive southward from a line crossing the drainage area through the headwaters of Big Slough and at Hesston, Kans. The total area of farm lands flooded was about 97,000 acres and the reported damage to crops amounted to $942,000. Damage to highways and bridges amounted to about $95,000 and to railroads about $335,250. In the city of Wichita, situated at the convergence of the Big and Little Arkansas Rivers and Chisholm Creek, the damage amounted to about $840,750, making a total for the district of about $2,213,000. About 6 square miles of the city was flooded. The crest stage in the Arkansas River at Wichita was 13.5 feet, 4.5 feet above the flood stage and the highest stage of record, and the river was above the flood stage from June 9 to 15, inclusive.

Previous high-water stages were 11 feet on May 18, 1877, 11.2 feet on Jan. 13, 1910, and 12.1 feet on June 6, 1921. The city overflow water came from the smaller

streams, the main river overflowing only a little property in the southern portion of the city. Since 1904 the river channel has been artificially deepened by the pumping of sand for commercial purposes, and the maximum deepening has been about 7 feet. Below Wichita the overflow was as great as in 1904.

Warnings were issued in ample time for Wichita and vicinity, but it was not possible to reach the upper portion of the flooded area, as the rapid rise of the streams followed too closely the heavy rains of the afternoon and evening of June 8. Appreciation of the excellent service was general, and a number of commendatory letters was received.

Below Wichita, Kans., to Fort Smith, Ark., including tributaries, except the Canadian River.—The floods over this district were much more extensive and destructive than elsewhere. The flood period lasted from June 9 to 22, inclusive, and the highest stages of record were experienced at four stations, Yonkers, Okla., on the Neosho River, and Ralston, Tulsa, and Tamaha, Okla., on the Arkansas River. Only the breaking of levees prevented record stages at Fort Gibson, Okla., on the Neosho River and at all places on the Arkansas River from Tulsa, Okla., to Fort Smith, Ark.

The floods were also unusual in that the causative rainfall occurred mainly over the northern and western portions of the district and beyond. Six different rises from six different sources occurred in the lower Arkansas River in eight days, the first from eastern Oklahoma, the second from the Canadian River, the third from the Neosho River, the fourth from the Cimarron River, the fifth from the upper Arkansas River, and the sixth from the Spring River, a tributary of the Neosho River in southwestern Missouri and northeastern Oklahoma. At no time since the beginning of gage readings have the Neosho and upper Arkansas Rivers shown such high stages simultaneously as during this flood. The severest floods passed through a country rich in agricultural and mineral resources, and in a high state of development, and the resulting damage far exceeded any previous records.

The losses in the district were estimated at $15,988,300, divided as follows:

Railroads (incomplete)	$1,505,300
Buildings, etc	8,922,000
Crops, mature	283,000
Crops, prospective	3,294,000
Movable property and live stock	774,000
Suspension of business	1,210,000

The acreage of overflowed lands was estimated at 191,820. The district most affected was Cowley County, Kans., and adjoining territory. The reported losses totaled $10,240,000, with the Winfield, Kans., section as the heaviest loser. Here 50,000 acres of land were overflowed, and the total losses were about $2,500,000. Losses in Kay County, Okla., amounted to $1,440,000.

Seven lives were lost during the flood.

The warnings of these floods were issued promptly and as frequently as occasion demanded, and the reported value of property saved thereby was $1,130,000.

Canadian River drainage area.—Excessive rains over central and northwestern Oklahoma on May 21–22, 1923, caused a general flood in the North Fork of the Canadian River. Warnings were issued on the morning of May 22, and again on May 26, the warnings of the latter date including a statement that the river east of Oklahoma City would go over its banks during the following week. Another heavy rain necessitated an additional warning on the morning of May 28.

The crest stages reached were from 3 to 4 feet above the flood stages, as a rule, and high water continued at the close of the month, and one life was lost, that of a man engaged in rescue work in Oklahoma City.

New high-water records were established at each of the four river stations on the North Canadian River. The stages are shown in the table at the end of this report.

Warnings were issued for these floods at the proper time, and their distribution was facilitated by the hearty cooperation of the State board of agriculture, both physically and financially. The newspapers also performed valuable service, as flood waters in the Canadian River move very slowly, and press warnings reached every community several days in advance of the crest of the flood.

It has been impossible to obtain even a rough estimate of the amount of damage. The figures submitted were so indefinite, incomplete and conflicting as to be valueless. It is known that the overflowed acreage was less than in the May flood, and the total loss and damage for the two floods probably aggregates between $5,000,000 and $10,000,000, of which several millions fell to Oklahoma City.

While the June rise in the Canadian River was decided, flood stages were not reached except locally at a few places. Warnings were issued immediately after the heavy rains of June 7–9, and there was very little loss or damage. In the Cimarron River the flood was destructive, and railroad traffic over north-central Oklahoma was suspended for about one week. No flood service is maintained on this river.

Arkansas River below Fort Smith, Ark.; White and Black Rivers.—The flood in this district formed a part of the general flood scheme. The Arkansas River flood was of about the same duration as farther westward, but it was neither so severe nor destructive.

In the lower White and Black Rivers the floods were more prolonged.

Frequent warnings were issued for the floods, and preventable losses were reduced to a minimum. The reports of losses, which were very incomplete, totaled $1,189,700, of which $1,107,000 was in crops, matured and prospective. A live-stock loss of $500 was due to the unexpected breaking of a levee, and the reported amount of property saved by the warnings was $45,500.

Rivers of Kansas, except the Arkansas River.—(Summarized from the report of Mr. S. D. Flora, Topeka, Kans.) The same rainfall conditions that caused the great flood in the Arkansas and Canadian Valleys, also caused general, although much more moderate, floods in the other rivers of Kansas. The Solomon, Republican, Smoky, Hill and Osage Rivers were in flood between June 9 and 14, doing damage to the estimated amount of $382,800, mainly to bridges and growing crops. Bankful stages only prevailed in the Blue River, and only a few hundred acres of growing crops were damaged. The greatest losses occurred over a limited area along the Republican River just below the Nebraska line. No towns were flooded except Scandia, Kans., within the area just mentioned, and the lower portion of Ottawa on the Osage. Personal property loss was insignificant.

Timely and very accurate warnings were issued for the Kansas River and Osage, and many thousands of dollars' worth of property were saved. The following quotation from the "Topeka Daily Capital" of June 17, 1923, indicates the value of the warnings.

All sorts of rumors of cloudbursts and great rises above were circulated by irresponsible persons, but North Topeka stood pat on the official prediction, took whatever precautions were necessary for a

twenty-one foot stage, and refused to be stampeded. The results entirely vindicated their faith in the bureau's prediction.

Sunday evening, after the heavy downpour, when the river stood almost on a level with North Kansas Avenue, many of the north siders were almost panic-stricken but in half an hour's time the Weather Bureau had received reports from its observers upstream that showed there was no chance for an overflow from this rain and North Topeka went to bed feeling that its levess would take care of all the water that was coming. This particular warning cost the Weather Bureau exactly 90 cents in telegraph and telephone tolls and a few hours of the hardest kind of work on the part of employees already worn out with long vigil over flood conditions, but it saved North Topeka upwards of $25,000, besides all the inconvenience of moving out and moving back again.

Warnings for other sections were equally accurate and allayed the fears of thousands of people who had become panic-stricken through unfounded and grossly exaggerated rumors.

South Platte and Loup Rivers of Nebraska.—(From report of Mr. M. V. Robins, Omaha, Nebr.) Early in this report it was stated that floods occurred in northeastern Colorado. The flood waters in the South Platte River moved through the State of Nebraska, causing a considerable rise in the river. Warnings were first issued on June 13, and again on June 15, 16, 17, and 18. The flood was a moderate one, and the only damage reported, amounting to about $5,500, was in the vicinity of Ogallala, Nebr., with an offset of $1,500 worth of property saved through the warnings. At North Platte, Nebr., no damage was done, and the money value of property saved by the warnings was $50,000.

On June 18 there were more heavy rains over the upper South Platte drainage area and that of the Loup River in Nebraska, and warnings were again issued on June 19. This flood caused considerable damage along the Platte River (below North Platte, Nebr.), and in the Loup Valley, the total amounting to about $300,000, mainly to crops and live stock. It was impossible to obtain estimates of the value of property saved through the warnings, but it was reported that a number of herds of cattle was saved.

These floods were the first since the recent organization of flood service along the Platte River, and the success attending the warnings was very gratifying. It became apparent that some further extensions are necessary if the needs of the people are to be met, and additions will be made if funds can be obtained.

The Platte, Kansas, and Osage floods were just about sufficient to bring the Missouri River to approximate flood stages from Kansas City eastward. Some warnings were issued at the proper time and apparently little or no damage was done.

The Santee River of South Carolina fell below the flood stage on June 12. The river had been above flood stage so long that no crops of consequence had been planted in the lowlands, and livestock kept within bounds. There were therefore no losses. The local floods in the Oconee, Ocmulgee and Flint Rivers of Georgia and in the Apalachicola River of Florida were unimportant.

The St. Francis River of Arkansas reached the flood stage of 17 feet at Marked Tree, Ark., on May 18, and did not fall below that stage until June 19. The highest stage was 19.1 feet from May 28 to June 1. Warnings were first issued on May 16, and thereafter as occasion required, the last on June 11, after the heavy rains of June 10–11.

The flood was not as destructive as its height and the season of the year would indicate. The absence of high stages in the Mississippi River prevented ponding in the lower reaches and the wet spring had seriously retarded farming operations. About 10,000 acres of land were overflowed and their crops destroyed, although perhaps one-half was replanted to corn. Lumbering operations were aided in some localities and hindered in others. The most serious loss was in farm labor which moved away from the flooded area and for the most part failed to return.

Losses were about $275,000, of which $200,000 was in crops about equally divided between mature and prospective yields. Property to the value of $50,000, was saved through the warnings.

The Yazoo River flood ended about July 4, the river having been in flood since March 1. The only losses resulted from the overflow of about 1,500 acres of cultivable lands, and were, of course, prospective. They were estimated at $15,000.

Five hundred and sixty-eight square miles of land in the lower basin were overflowed by backwater from the Mississippi River, but owing to the frequency of floods, cultivation of the lands in this section has virtually been abandoned, There still remain about 2,140 square miles that are protected from overflow.

LOW WATER IN THE MISSISSIPPI RIVER DURING JUNE, 1923, IN THE DAVENPORT, IOWA, DISTRICT.

By A. M. HAMRICK, Meteorologist.

[Weather Bureau, Davenport, Iowa.]

During June, 1923, the Mississippi River was far below the average stage for that month in the Davenport, Iowa, district. Gage readings at Davenport show that in only four of the last fifty years have June river stages averaged lower than this year. The lowest water for any June occurred in 1900, when the daily gage readings averaged 2.2 feet, with a low stage for the month of 1.4 feet, and a high stage of 3.2 feet. The other three low-water Junes were: 1891, with an average stage of 2.8 feet; 1910, with an average stage of 3.1 feet; and 1887, with an average stage of 3.2 feet. In June, 1923, the average river stage was 3.5 feet, with a high reading of 4.3 feet, and a low reading of 3 feet.

The normal stage of the Mississippi River for June at Davenport, as determined from the records of the last 50 years, is 7.24 feet.

No flood occurred in this section of the Mississippi River during the spring of 1923, although the April stages averaged slightly above normal. The May stages were 1.7 feet below normal.

The total rainfall at Davenport during May was 3.60 inches, 0.59 inch below normal, and during June it was 6.03 inches, or 1.92 inches above normal. A drought prevailed throughout this section of the Mississippi Valley during April, and the heavy rains in May and June had very little effect upon the stages of the river.

The accompanying table gives the average daily river stages at Davenport for June for the last 50 years.

	Average stage (feet).		Average stage (feet).
June 1873	11.2	1899	9.2
1874	5.5	1900	2.2
1875	7.3	1901	3.6
1876	9.5	1902	7.3
1877	5.4	1903	9.9
1878	5.1	1904	8.1
1879	5.4	1905	11.3
1880	12.3	1906	9.6
1881	8.2	1907	7.0
1882	8.8	1908	11.5
1883	8.1	1909	8.4
1884	6.8	1910	3.1
1885	6.5	1911	4.4
1886	4.3	1912	6.8
1887	3.2	1913	6.3
1888	10.7	1914	7.7
1889	4.2	1915	7.9
1890	9.0	1916	11.3
1891	2.8	1917	7.5
1892	14.8	1918	8.2
1893	8.0	1919	6.1
1894	6.8	1920	7.2
1895	3.5	1921	5.9
1896	7.9	1922	4.8
1897	5.9		
1898	5.5	50-year mean	7.24

As a result of the excessive rains of June 9–10, the upper Trinity River of Texas overflowed low places from

above Bridgeport to below Trinidad from June 10 to 23, inclusive. The crest stages were not unusually high, and flood stages occurred only above Long Lake. The crest reached the mouth of the river on July 3. The total reported losses were $20,000, while property to the value of $49,000, was reported saved by the flood warnings.

Colorado drainage, Colorado and Utah, etc.—(From report by Mr. F. W. Brist, Denver, Colo.) Owing to the prevailing high temperatures at high elevations warnings of moderate floods were issued on June 14 for the upper Colorado River and its tributaries. These warnings were well verified, and crest stages were reached between June 16 and 18.

Notice of decreasing stages at Yuma, Ariz., by June 10, was sent to lower Colorado River points on June 7. The crest of 25.4 feet occurred on June 10. Another rise set in on June 13, and warnings were again issued on June 16 for a discharge of 92,000 second-feet by June 28. The maximum discharge was 92,000 feet on June 27, with a stage of 24.3 feet. At Grand Canyon, Ariz., 100,000 second-feet was forecast by June 19, with a crest of 25.5 feet, and on June 18 and 19, the discharge was 98,800 second-feet, with a stage of 24.9 feet.

On June 22 it became evident that the melting of snow over the upper area had about ceased, and a decreasing stage at Yuma after June 27 was forecast. The crest stage at Yuma was 25.4 feet on June 8 and 10.

Annual rise of the Columbia River.—The Columbia and extreme lower Willamette Rivers were still in flood at the close of the month, and the report on the flood will appear in the MONTHLY WEATHER REVIEW for July, 1923.

Flood stages during June, 1923.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Santee:	*Feet.*			*Feet.*	
Rimini, S. C	12	(1)	11	14.1	4
Ferguson, S. C	12	(1)	12	13.3	5
Oconee:					
Milledgeville, Ga	22	(1)	1	23.8	1
Ocmulgee:					
Macon, Ga	18	(1)	1	18.0	1
Abbeville, Ga	11	(1)	10	14.9	3-4
Lumber City, Ga	15	5	10	17.2	7
EAST GULF DRAINAGE.					
Apalachicola:					
River Junction, Fla	12	(1)	10	16.3	1
Flint:					
Albany, Ga	20	(1)	2	21.0	1
Tombigbee:					
Lock No. 4, Ala	39	(1)	5	46.4	2
Pearl:					
Jackson, Miss	20	(1)	5	23.0	3
West Pearl:					
Pearl River, La	13	(1)	6	14.7	1-2
MISSISSIPPI DRAINAGE.					
White, W. Fork:					
Edwardsport, Ind	10	1	1	11.7	1
Holston, N. Fork:					
Mendota, Va	8	12	14	14.8	13
St. Francis:					
Marked Tree, Ark	17	(1)	19	19.1	1
Arkansas:					
Fort Lyon, Colo	6	4	4	6.0	4
Do	6	8	8	6.4	8
Do	6	17	17	10.0	17
Wichita, Kans	9	9	15	13.5	10
Ralston, Okla	12	3	4	12.6	3
Do	12	10	18	23.0	11
Tulsa, Okla	16	12	14	19.8	13
Webbers Falls, Okla	23	12	20	29.4	14
Fort Smith, Ark	22	11	21	29.4	15
Dardanelle, Ark	20	(1)	1	20.0	1
Do	20	12	23	26.5	17
Little Rock, Ark	23	14	22	25.3	18
Pine Bluff, Ark	25	(1)	1	25.0	1
Do	25	15	25	27.7	19-20
Little Arkansas:					
Sedgwick, Kans	18	9	13	24.7	11
Do	18	18	19	18.5	19

[1] Continued from May.

Flood stages during June, 1923—Continued.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
MISSISSIPPI DRAINAGE—continued.					
Neosho:		*Feet.*		*Feet.*	
Neosho Rapids, Kans	22	10	14	27.0	11
LeRoy, Kans	24	10	16	27.3	13
Iola, Kans	15	10	17	19.5	15
Oswego, Kans	17	10	22	22.2	16, 19-20
Wyandotte, Okla	23	15	15	24.5	15
Yonkers, Okla	14	10	....	27.6	16
Fort Gibson, Okla	22	10	21	32.0	14
Cottonwood:					
Emporia, Kans	20	10	14	25.1	10
Canadian:					
Canadian, Tex	5	9	9	5.5	9
Union City, Okla	7	10	10	8.2	10
North Canadian:					
Woodward, Okla	3	1	14	8.3	10
Canton, Okla	4	3	3	5.0	3
Do	4	9	11	8.6	10
Reno Junction, Okla	12	12	13	14.0	12
Oklahoma City, Okla	12	(1)	1	12.1	1
Do	12	7	9	13.5	7
Do	12	12	17	16.3	14
Petit Jean:					
Danville, Ark	20	11	13	22.2	12
White:					
Newport, Ark	26	(1)	1	26.6	1
Georgetown, Ark	22	(1)	20	25.8	1
Clarendon, Ark	30	(1)	8	30.4	3-5
Black:					
Black Rock, Ark	14	(1)	21	20.3	12
Cache:					
Patterson, Ark	9	(1)	3	9.9	1
Do	9	10	23	10.2	12-13
Yazoo:					
Yazoo City, Miss	25	(1)	(2)	28.3	6-13
Tallahatchie:					
Swan Lake, Miss	25	(1)	21	28.5	1
Missouri:					
Waverly, Mo	23	13	14	23.2	13
St. Charles, Mo	25	15	17	25.7	17
Meramec:					
Pacific, Mo	11	18	18	12.0	18
Kansas:					
Topeka, Kans	21	10	10	21.6	10
Smoky Hill:					
Lindsborg, Kans	19	10	11	21.2	11
Solomon, Kans	24	11	14	25.9	13
Solomon:					
Beloit, Kans	13	9	14	24.4	12
Niles, Kans	24	11	12	26.6	11
Republican:					
Scandia, Kans	10	12	12	11.4	12
Clyde, Kans	17	13	13	17.2	13
Wakefield, Kans	12	5	5	12.4	5
Do	12	14	14	12.2	14
Blue:					
Blue Rapids, Kans	20	11	11	21.4	11
Grand:					
Brunswick, Mo	10	10	17	12.5	15
Do	10	29	(2)	11.1	30
Osage:					
Ottawa, Kans	24	11	13	28.1	12
Osceola, Mo	20	17	18	20.2	17
Warsaw, Mo	22	15	18	23.4	17
WEST GULF DRAINAGE.					
Trinity:					
Dallas, Tex	25	11	18	37.5	12
Trinidad, Tex	28	14	23	39.3	17-18
Rio Grande:					
San Marcial, N. Mex	1	(1)	5	1.6	1
Do	1	11	14	1.2	12
Do	1	18	22	1.0	18-22
COLORADO DRAINAGE.					
Colorado:					
Lees Ferry, Ariz	12	(1)	(2)	17.0	1
Topock, Ariz	14	(1)	10	17.5	3
Do	14	19	23	15.2	22
Parker, Ariz	7	(1)	(2)	10.4	23
Roaring Fork:					
Carbondale, Colo	5	17	18	5.2	18
Do	5	26	26	5.0	26
Green:					
Elgin, Utah	12	(1)	4	12.9	1
Do	12	15	19	12.2	16-17
COLUMBIA BASIN DRAINAGE.					
Columbia:					
Marcus, Wash	24	(1)	(2)	30.1	18-19
Wenatchee, Wash	40	17	19	40.6	19
Vancouver, Wash	15	(1)	(2)	20.6	16-17
Kootenai:					
Bonners Ferry, Idaho	26	11	17	27.4	14
Pend Oreille:					
Newport, Wash	16	15	20	16.2	16-18
Willamette:					
Portland, Oreg	15	(1)	(2)	19.8	16

[1] Continued from May. Continued into July.

MEAN LAKE LEVELS DURING JUNE, 1923.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., July 9, 1923.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during June, 1923:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	601.67	579.86	572.02	245.93
Above or below—				
Mean stage of May, 1923	+0.02	+0.26	+0.15	+0.31
Mean stage of June, 1922	−0.47	−0.71	−0.85	−0.82
Average stage for June, last 10 years	−0.76	−1.09	−1.00	−0.95
Highest recorded June stage	−1.76	−3.74	−2.50	−2.70
Lowest recorded June stage	+0.43	−0.04	+0.45	+1.04
Average relation of the June level to—				
May, level	....	+0.20	+0.20	+0.20
July, level	....	−0.10	0.00	0.00

[1] Lake St. Clair's level: In June, 574.71 feet.

EFFECT OF WEATHER UPON CROPS AND FARMING OPERATIONS, JUNE, 1923.

By J. B. KINCER, Meteorologist.

June was too wet for wheat during the first half of the month in Kansas and Oklahoma, with complaints of grain lodging from too rank growth; elsewhere winter wheat made mostly satisfactory progress, especially in the more northwestern States, where widespread rains were beneficial. The month, on the whole, was favorable for spring wheat, except during the week ending June 19, which was decidedly detrimental in North Dakota and northern Minnesota because of deficient rainfall, high temperatures, and hot winds, especially on lands where the crop was not well seeded.

Wheat ripened rapidly during the latter part of the month under the influence of warm weather, and harvest was in progress by the 25th northward to portions of Maryland and eastern Kansas. The cool weather the last of the month was more favorable for spring wheat, with exceptionally favorable conditions prevailing in South Dakota and Montana. Oats improved in most Northern States, but were heading short in interior sections east of the Mississippi River. Rain was very beneficial for this crop in the extreme upper Mississippi Valley, while conditions were favorable in the northern Plains.

The weather was favorable for corn, as a rule, during much the greater part of the month. The drier weather in the upper Mississippi Valley was very helpful in permitting farmers to overcome weedy fields, while warmth produced rapid growth until the cool wave near the close of the month. Corn was fairly well cultivated in the Ohio Valley States, except where it was too wet in the southern portions of Indiana and Illinois, and in western Kentucky. The crop made vigorous, healthy growth in the extreme lower Missouri Valley.

Better cotton weather was experienced than during the preceding month, particularly in the east Gulf States where less rainfall permitted much needed cultivation, although some sections continued too wet. Cotton made fair to very good progress in the more western portion of the belt, except that late-planted needed more moisture in parts of Texas. At the close of the month the cotton crop was considerably later than in an average season.

There was insufficient rain for pastures and hay crops in many localities from the upper Mississippi Valley eastward, but grasses were in fine condition in the central and northern Plains, except in a few dry localities. The weather was exceptionally favorable for ranges and stock in the central and northern Rocky Mountain-Plateau districts, particularly in the Northwest, but rain was needed in much of the Southwest, especially in western New Mexico and in Arizona. The weather was generally favorable for fruit in practically all sections of the country.

CLIMATOLOGICAL TABLES.[1]

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	77.1	−1.1	3 stations	98	[2] 21	Valley Head	45	29	4.03	−0.18	Robertsdale	14.07	Prattville	1.23
Alaska														
Arizona	72.1	−3.2	Mohawk	118	29	Fort Valley	22	17	0.02	−0.31	Elgin	0.36	75 stations	0.00
Arkansas	76.7	−0.1	4 stations	99	[2] 26	Dutton	46	29	5.20	+1.12	Marshall	12.14	Princeton	1.50
California	63.0	−5.3	Greenland Ranch	120	30	Summit	20	1	0.62	+0.29	Giant Forest	4.75	51 stations	0.00
Colorado	59.9	−0.8	Las Animas	102	24	2 stations	20	[2] 1	2.19	+0.85	Fort Collins	6.23	3 stations	0.00
Florida	79.1	−0.7	Malabar	98	13	3 stations	59	[2] 2	8.89	+2.36	Quincy	15.59	Cedar Keys	1.76
Georgia	76.6	−1.6	2 stations	99	[2] 8	Blue Ridge	43	30	5.23	+0.60	Bainbridge	11.81	Concord	1.44
Hawaii	72.8	−0.2	Waianac	90	26	Volcano Observatory	49	2	3.03	−1.54	Honomu	19.82	9 stations	0.00
Idaho	57.6	−2.1	2 stations	104	30	Stanley	12	15	2.74	+1.40	Mussel Shell R. S	6.61	Geneva	0.52
Illinois	73.2	+1.7	....do	103	23	2 stations	40	29	3.50	−0.35	Grafton	5.84	Danville	1.48
Indiana	73.0	+1.6	Collegeville	103	22	3 stations	40	[2] 29	3.45	−0.39	Columbus	6.31	Lafayette	1.26
Iowa	70.9	+1.8	Clarinda	100	25	2 stations	40	[2] 9	4.93	+0.38	Oelwein	7.69	Postville	2.43
Kansas	73.0	−0.1	Hutchinson	103	25	Bison	42	29	6.10	+2.15	Wichita	14.43	Hudson	2.70
Kentucky	73.8	+0.1	2 stations	99	22	Greensburg	42	30	4.59	0.41	Jackson	8.98	Cynthiana	2.10
Louisiana	79.4	−0.6	3 stations	99	[2] 23	2 stations	52	30	6.55	+1.68	New Iberia	12.12	Newellton	2.38
Maryland-Delaware	73.7	+3.1	Cumberland, Md	102	[2] 21	Oakland, Md	34	10	2.97	−1.11	Oakland, Md	7.65	Wilmington, Del	1.15
Michigan	66.9	+3.5	Morenci	102	24	Wellston	30	29	2.62	−0.47	Iron Mountain	8.55	Hastings	1.00
Minnesota	68.4	+3.9	3 stations	97	[2] 1	2 stations	32	8	4.62	+0.58	Fergus Falls	10.21	Argyle	1.25
Mississippi	77.7	−0.9	7 stations	97	7	Batesville	48	30	5.24	+0.99	Woodville	11.39	Corinth	1.53
Missouri	73.5	+0.2	Caruthersville	103	22	6 stations	45	[2] 29	5.48	+1.02	Nevada	9.36	Farmington	2.77
Montana	59.6	−0.2	Bridger	103	30	Wisdom	16	14	3.99	+1.29	Sentinel Butte Pass	11.32	Bridger	0.98
Nebraska	69.2	−0.1	Falls City	103	25	Gordon	38	7	4.70	+0.92	Genoa	9.10	Sutherland	1.31
Nevada	60.0	−5.1	Logandale	113	30	Rye Patch	16	13	1.23	+0.79	Vya	3.25	5 stations	0.00
New England	65.3	+1.4	New Bedford, Mass	102	[2] 21	Van Buren, Me	26	[2] 12	2.84	−0.41	Storrs, Conn	6.07	Van Buren, Me	0.77
New Jersey	72.5	+3.8	Belle Plain	106	21	Belle Plain	37	1	2.08	−1.70	Dover	5.44	Pleasantville	0.72
New Mexico	68.7	+0.2	Orogrande	110	25	Luna R. S	24	4	1.50	+0.02	Clovis	12.31	26 stations	0.00
New York	66.5	+1.7	Medford	100	21	Gabriels	27	15	3.49	−0.10	Skaneateles	6.18	Mount McGregor	1.71
North Carolina	74.5	+1.6	2 stations	101	[2] 26	Mount Mitchell	31	30	2.38	−2.72	Parker	11.17	Pinehurst	0.40
North Dakota	66.1	+3.3	....do	100	[2] 16	Hansboro	30	6	3.82	+0.32	Power	10.27	Energy	0.91
Ohio	71.0	+1.9	4 stations	100	[2] 20	Green Hill	36	14	3.38	−0.50	Middleport	7.69	Defiance	0.93
Oklahoma	77.2	+0.7	Mangum	108	27	2 stations	47	29	5.01	+0.87	Wyandotte	10.28	Eufaula	1.63
Oregon	59.0	−1.1	Echo	106	29	Fremont	21	2	1.85	+0.47	Cornucopia	5.42	Merrill	0.25
Pennsylvania	70.9	+3.3	Lancaster	103	20	West Bingham	32	30	2.73	−1.76	Creekside	7.99	Bethlehem	0.41
Porto Rico	77.8	−0.6	Arecibo	98	1	Utuado	56	20	4.31	−2.30	Coloso	10.83	San German	0.34
South Carolina	77.1	−0.4	Newberry	101	27	Liberty	49	30	2.31	−2.52	Due West	6.48	Gaston Shoals	0.55
South Dakota	67.0	+1.7	Wagner	104	24	Pine Ridge	33	7	4.53	+1.20	Oelrichs	8.21	Wagner	1.57
Tennessee	74.4	−0.2	2 stations	99	[2] 21	Waynesboro	43	30	4.17	−0.19	Clarksville	7.12	Florence	1.68
Texas	81.0	+0.8	Fort McKavett	109	[2] 26	Clint	45	[2] 1	2.96	−0.23	Kaufman	11.81	2 stations	0.00
Utah	61.0	−3.4	St. George	108	[2] 29	Panquitch	18	1	0.57	−0.08	Lower Mill Creek	2.48	11 stations	0.00
Virginia	73.7	+2.7	Danville	103	22	Burkes Garden	34	30	3.01	−1.77	Marion	11.17	Hopewell	0.77
Washington	60.5	−0.3	Trinidad	105	30	Paradise Inn	23	13	1.85	+0.48	Mill Creek	7.84	Granger	0.04
West Virginia	70.2	+1.3	Wardensville	102	54	4 stations	35	[2] 10	4.54	+0.27	Buckhannon	10.37	Upper Tract	1.25
Wisconsin	68.5	+4.0	2 stations	99	24	Merrill	30	29	4.70	+0.64	Park Falls	11.26	Manitowoc	1.13
Wyoming	58.3	−0.6	Sage	96	11	Brooks Lake	19	13	2.06	+0.51	Yoder	5.92	Green River	0.03

[1] For description of tables and charts, see REVIEW, July, 1922, pp. 384–385.

[2] Other dates also.

TABLE I.—*Climatological data for Weather Bureau stations, June, 1923.*

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Temperature of the air: Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Days with 0.01, or more.	Wind: Total movement.	Wind: Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0–10	In.	In.
New England.							**65.0**	**+ 1.5**										**74**	**2.74**	**− 0.4**										**5.4**		
Eastport	76	67	85	29.70	29.78	− .15	56.1	+ 1.0	84	19	66	41	14	46	34	51	48	79	2.74	− 0.5	11	5,735	s.	33	n.	9	3	12	15	7.0	0.0	0.0
Greenville, Me	1,070	6		28.66	29.81		60.4		90	19	72	35	13	48	38				3.78		12						18	2	10		0.0	0.0
Portland, Me	103	82	117	29.72	29.84	− .11	64.4	+ 1.9	96	20	74	45	13	55	33	57	51	66	2.89	− 0.5	8	6,179	w.	35	n.	5	11	11	8	5.1	0.0	0.0
Concord	288	70	79	29.53	29.83	− .13	66.2	+ 3.3	95	19	79	41	1	54	44				1.42	− 1.9	7	3,545	w.	25	w.	27	19	9	2	3.5	0.0	0.0
Burlington	404	11	48	29.42	29.84	− .12	63.6	− 0.2	92	20	74	40	13	53	36				3.76	+ 0.5	10	5,510	n.	28	nw.	27	8	9	13	5.9	0.0	0.0
Northfield	876	12	60	28.93	29.86	− .10	61.6	− 1.1	91	19	75	34	13	48	45	58	56	81	2.94	− 0.3	12	4,331	s.	28	sw.	26	7	12	11	6.0	0.0	0.0
Boston	125	115	188	29.71	29.84	− .12	69.3	+ 2.8	96	19	79	47	9	60	33	61	55	65	2.03	− 1.0	7	7,093	w.	35	w.	27	6	18	6	5.7	0.0	0.0
Nantucket	12	14	90	29.84	29.84	− .14	62.4	+ 1.1	90	21	70	46	13	55	27	58	55	80	1.27	− 1.1	8	10,804	sw.	42	sw.	1	11	12	7	5.2	0.0	0.0
Block Island	26	11	46	29.83	29.86	− .11	63.0	+ 1.2	88	21	70	49	9	56	25	59	57	84	1.81	− 1.1	12	11,029	sw.	42	sw.	1	9	13	8	5.1	0.0	0.0
Providence	160	215	251	29.68	29.85	− .12	68.4	+ 0.1	95	21	78	46	9	59	33	61	56	68	4.31	+ 1.2	12	7,925	w.	56	w.	26	8	10	12	5.8	0.0	0.0
Hartford	159	122	140	29.68	29.85	− .12	70.0	+ 2.9	95	20	81	48	9	59	34	62	59	71	3.84	+ 0.8	12	4,918	s.	42	sw.	26	9	7	14	5.9	0.0	0.0
New Haven	106	74	153	29.76	29.87	− .10	69.8	+ 3.2	95	20	79	50	1	60	29	62	58	71	3.13	0.0	13	5,570	sw.	36	nw.	6	13	11	6	4.3	0.0	0.0
Middle Atlantic States.							**73.0**	**+ 2.7**										**68**	**2.35**	**− 1.3**										**4.2**		
Albany	97	102	115	29.76	29.86	− .11	69.6	+ 1.6	96	5	80	49	16	59	34	61	56	64	3.07	− 0.7	11	4,457	s.	24	nw.	9	19	6	5	2.9	0.0	0.0
Binghamton	871	10	84	29.03	29.88	− .09	68.4	+ 2.2	93	19	81	41	16	56	40				3.64	0.0	14	3,318	nw.	30	sw.	26	11	8	11	5.1	0.0	0.0
New York	314	414	454	29.56	29.88	− .10	72.0	+ 3.2	95	20	81	51	1	63	27	63	57	65	1.86	− 1.4	8	11,223	nw.	60	sw.	26	11	9	10	5.2	0.0	0.0
Harrisburg	374	94	104	29.54	29.92	− .07	74.0	+ 3.7	98	21	84	54	30	64	29	64	58	64	2.30	− 1.2	12	4,326	w.	34	nw.	3	6	13	11	6.2	0.0	0.0
Philadelphia	114	123	190	29.78	29.90	− .09	75.8	+ 4.4	99	21	86	54	1	66	29	64	58	57	0.65	− 2.6	6	6,943	nw.	40	n.	9	12	12	6	4.5	0.0	0.0
Reading	325	81	98	29.56	29.90		74.8		101	20	85	52	30	64	31	65	61	67	0.54	− 3.1	9	2,510	nw.	24	sw.	26	14	11	5	4.1	0.0	0.0
Scranton	805	111	119	29.07	29.91	− .07	70.2	+ 3.0	95	20	82	44	16	58	34	63	59	71	3.05	− 0.5	13	4,620	s.	36	sw.	26	9	12	9	5.1	0.0	0.0
Atlantic City	52	37	172	29.84	29.90	− .08	70.8	+ 4.2	95	2	78	53	14	63	34	64	61	75	0.93	− 2.1	7	11,779	sw.	50	nw.	8	19	7	4	3.0	0.0	0.0
Cape May	18	13	49	29.92	29.94	− .04	71.4	+ 3.7	96	25	80	52	14	63	30	65	62	78	1.69	− 1.4	9	5,372	nw.	34	nw.	9	19	6	5	2.8	0.0	0.0
Sandy Hook	22	10	55	29.86	29.88		71.0		96	21	80	52	1	62	27	63	60	75	0.95		5	8,913	w.	46	nw.	9	12	13	5	4.5	0.0	0.0
Trenton	190	159	183	29.69	29.89		73.5		98	20	85	50	1	62	32	63	58	62	1.47	− 2.0	5	7,271	sw.	40	nw.	9	15	8	7	4.6	0.0	0.0
Baltimore	123	100	113	29.78	29.91	− .08	76.7	+ 4.0	100	21	86	58	9	67	26	66	61	62	1.84	− 2.0	9	4,010	sw.	24	sw.	26	19	7	4	3.3	0.0	0.0
Washington	112	62	85	29.81	29.92	− .08	75.6	+ 3.4	98	21	86	57	30	65	31	66	62	66	2.80	− 1.4	9	4,109	nw.	36	nw.	7	17	8	5	3.8	0.0	0.0
Lynchburg	681	153	188	29.23	29.95	− .06	75.6	+ 1.0	96	19	86	55	14	65	30	65	60	64	2.12	− 1.8	4	5,196	w.	33	n.	9	17	10	3	3.8	0.0	0.0
Norfolk	91	170	205	29.85	29.95	− .05	77.2	+ 2.8	95	28	86	59	14	68	25	68	64	70	1.43	− 2.9	6	9,060	sw.	42	nw.	9	17	8	5	3.9	0.0	0.0
Richmond	144	11	52	29.80	29.94	− .07	76.0	+ 0.9	97	28	87	54	10	65	29	67	62	65	2.09	− 1.4	9	5,405	sw.	34	nw.	7	12	15	3	4.2	0.0	0.0
Wytheville	2,304	49	55	27.68	29.99	− .02	68.4	− 0.3	86	19	79	44	30	58	32	62	60	80	8.07	+ 4.0	16	3,617	w.	27	w.	28	15	12	3	3.6	0.0	0.0
South Atlantic States.							**76.8**	**+ 0.1**										**74**	**3.00**	**− 1.9**										**5.2**		
Asheville	2,255	70	84	27.72	30.01	.00	69.8	+1.1	87	16	80	48	30	59	28	62	60	79	2.66	−1.5	16	4,047	nw.	44	nw.	27	8	19	3	4.8	0.0	0.0
Charlotte	779	55	62	29.17	29.99	−.02	77.0	+1.5	95	27	87	57	14	67	25	67	62	66	2.21	−2.2	7	2,939	sw.	23	nw.	8	11	8	11	5.2	0.0	0.0
Hatteras	11	11	50	29.96	29.97	−.04	75.8	+0.2	85	23	82	61	14	70	18	71	68	80	2.12	−2.2	6	9,594	sw.	33	n.	9	12	12	6	4.4	0.0	0.0
Manteo	12	5	42				76.4		97	24		53	10		30				1.00		3		s.				22	3	5		0.0	0.0
Raleigh	376	103	110	29.58	29.96	−.05	77.0	+1.9	95	25	87	58	14	67	27	67	62	64	1.37	−3.4	6	5,963	sw.	36	sw.	28	7	19	4	5.0	0.0	0.0
Wilmington	78	81	91	29.92	30.00	−.01	76.7	−0.1	93	28	85	60	1	69	25	71	68	78	1.80	−3.8	8	5,635	sw.	25	sw.	28	15	14	1	3.8	0.0	0.0
Charleston	48	11	92	29.96	30.01	.00	78.6	−0.3	93	28	85	65	2	72	19	72	69	75	3.58	−1.8	8	7,487	s.	32	w.	8	7	15	8	5.9	0.0	0.0
Columbia, S. C	351	41	57	29.63	30.00	−.01	77.8	−0.4	95	27	88	60	15	68	28	69	65	72	5.27	+1.1	10	4,660	s.	27	sw.	28	12	9	9	5.1	0.0	0.0
Due West	711	10	55	29.27	30.03		76.2		94	27	86	59	30	66	26				6.48		7	5,488	sw.	43	sw.	12	7	13	10	5.6	0.0	0.0
Greenville, S. C	1,039	113	122	28.91	29.98		75.8		96	27	86	57	30	66	31	67	63	70	1.73		8	5,579	w.	48	w.	7	10	15	5	4.9	0.0	0.0
Augusta	180	62	77	29.81	30.00	−.01	77.8	−0.9	96	27	87	60	2	68	26	69	66	72	4.21	−0.3	11	3,670	s.	37	nw.	27	9	11	10	5.5	0.0	0.0
Savannah	65	150	194	29.94	30.01	.00	78.4	−0.6	93	8	86	64	2	71	21	72	69	78	1.79	−4.2	10	7,857	s.	34	nw.	12	11	9	10	5.4	0.0	0.0
Jacksonville	43	209	245	29.96	30.01	.00	78.8	−1.1	91	27	85	68	9	73	23	72	70	80	4.94	−0.6	17	8,601	sw.	48	ne.	9	1	12	17	7.3	0.0	0.0
Florida Peninsula.							**80.2**	**−0.6**										**79**	**5.14**	**−1.7**										**6.3**		
Key West	22	10	64	29.98	30.00	+.01	81.6	−0.3	90	27	87	71	3	76	16	75	73	76	3.14	−1.1	11	5,911	se.	43	sw.	3	11	8	11	5.1	0.0	0.0
Miami	25	71	79	30.01	30.04		79.8	−0.6	92	29	86	66	1	74	19	74	72	78	5.94	−2.0	17	5,182	se.	29	n.	20	4	10	16	6.9	0.0	0.0
Sand Key	23	39	72	29.99	30.02	+.03	80.4		88	18	83	69	3	78	12	75	73	78	2.36		7	7,347	se.	54	e.	5	11	7	12	5.6	0.0	0.0
Tampa	35	79	87	29.98	30.01	.00	79.2	−0.8	90	21	85	68	1	73	18	74	72	84	6.33	−2.0	18	4,299	w.	27	e.	5	1	14	15	7.5	0.0	0.0
East Gulf States.							**77.3**	**−0.9**										**79**	**5.52**	**+0.9**										**5.8**		
Atlanta	1,174	190	216	28.80	30.01	.00	75.0	−1.0	91	21	83	55	30	66	23	68	64	74	3.23	−0.6	12	6,514	se.	33	w.	28	11	8	11	5.7	0.0	0.0
Macon	370	78	87	29.61	30.00	−.01	76.8	−0.3	94	20	86	58	30	68	27	69	66	74	9.91	+6.3	12	3,775	e.	23	s.	26	5	14	11	6.3	0.0	0.0
Thomasville	273	49	58	29.71	30.00	.00	77.6	−1.9	94	21	86	63	2	69	23	71	70	84	10.71	+6.0	20	2,951	sw.	20	nw.	16	1	11	18	8.0	0.0	0.0
Apalachicola	36	42	49	29.96	30.00		77.6		91	21	83	66	2	72	20	74	72	82	6.14		16	5,671	se.	33	e.	1	12	7	11	5.3	0.0	0.0
Pensacola	56	149	185	29.94	30.00	+.01	77.1	−2.2	88	21	82	63	21	72	25	73	71	83	12.71	+7.8	15	8,293	w.	52	ne.	21	2	12	16	7.2	0.0	0.0
Anniston	741	9	57	29.24	30.02	+.02	75.4	+0.4	95	21	86	50	30	65	31				3.20	−0.7	9	2,755	se.	19	w.	12	16	12	2	3.7	0.0	0.0
Birmingham	700	11	48	29.27	30.02	+.03	77.0	−1.2	94	21	86	53	30	68	25	68	65	73	2.10	−1.8	9	3,847	s.	22	s.	9	10	11	9	5.2	0.0	0.0
Mobile	57	125	161	29.93	29.99	.00	78.6	−1.0	93	21	86	63	30	71	26	73	72	86	5.97	0.0	14	5,897	se.	43	nw.	28	1	20	9	6.5	0.0	0.0
Montgomery	223	100	112	29.76	30.00	.00	78.6	−1.0	95	27	87	59	30	70	28	70	67	73	2.92	−1.3	9	4,124	se.	23	s.	25	9	10	11	5.7	0.0	0.0
Corinth	469	6					77.0		94	21	87	50	30	67	28				1.53		11		se.				3	25	2		0.0	0.0
Meridian	375	85	93	29.60	29.98	.00	76.8	−0.5	93	21	86	55	30	68	25	70	67	77	2.48	−2.1	11	3,178	e.	30	nw.	15	10	13	7	5.0	0.0	0.0
Vicksburg	247	65	73	29.72	29.99	+.02	78.0	−1.0	93	7	87	60	30	69	23	71	69	82	2.09	−2.4	9 9	4,141	se.	33	ne.	18	9	15	6	5.3	0.0	0.0
New Orleans	53	76	84	29.92	29.97	−.01	79.9	−0.7	90	26	87	67	30	73	21	74	73	81	5.38	−0.8	18	4,088	se.	19	sw.	27	2	18	10	6.1	0.0	0.0
West Gulf States.							**80.0**	**+0.9**										**74**	**2.50**	**−1.1**										**4.6**		
Shreveport	249	77	93	29.69	29.96	.00	79.7	+0.1	94	26	88	61	30	71	21	72	69	76	2.48	−1.1	10	4,378	se.	22	sw.	11	17	9	4	3.6	0.0	0.0
Bentonville	1,303	11	44				73.9	−0.2	92	27	83	51	29	65	29				6.40		13						9	13	8		0.0	0.0
Fort Smith	457	79	94	29.44	29.92	−.02	77.9	+1.1	97	26	87	59	29	69	25	70	67	74	3.72	−0.3	10	5,069	e.	44	w.	1	8	14	8	5.6	0.0	0.0
Little Rock	357	136	144	29.57	29.94	−.02	77.5	+0.1	93	22	86	60	30	69	23	70	68	75	1.80	−2.3	11	5,245	s.	44	nw.	28	9	13	8	4.9	0.0	0.0
Brownsville	57	53	61	29.80	29.86		83.0		92	26	90	73	7	76	18	75	73	79	1.98		10	6,310	se.	25	s.	10	14	11	5	3.8	0.0	0.0
Corpus Christi	20	11	73	29.88	29.90	−.01	82.6	+2.0	91	28	87	74	30	78	14	76	74	78	0.53	−2.2	6	10,821	se.	36	se.	8	14	12	4	4.4	0.0	0.0
Dallas	512	109	117	29.38	29.91		80.4		98	27	89	64	5	72	23				8.99		8	6,633	se.	29	nw.	5	14	11	5	4.3	0.0	0.0
Fort Worth	670	106	114	29.18	29.88	−.04	80.6	+0.5	100	27	90	62	9	71	26	70	66	67	6.74	+3.8	7	7,503	e.	34	w.	5	10	16	4	4.5	0.0	0.0
Galveston	54	106	114	29.89	29.95	.00	81.4	+0.7	88	27	86	68	29	77	17	75	73	78	3.24	−1.5	12	8,024	se.	28	se.	10	11	15	4	4.8	0.0	0.0
Groesbeck	461	11	56	29.44	29.90		81.0		97	27	91	64	30	71	26				0.18		3	7,733	se.	34	se.	9	11	16	3	4.5	0.0	0.0
Houston	138	111	121	29.78	29.92		81.6	+0.6	95	28	90	68	30	73	25				6.79		13	5,619	se.	29	n.	28	5	21	4	5.3	0.0	0.0
Palestine	510	64	72	29.41	29.93	−.01	80.0	+1.0	94	26	89	64	30	71	22	72	69	74	1.41	−2.6	8	4,268	se.	24	sw.	3	9	19	2	4.9	0.0	0.0
Port Arthur	34	58	66	29.90	29.94		81.0		90	26	87	68	28	76	21	75	72	77	2.81		10	6,107	se.	28	e.	7	17	12	1	3.5	0.0	0.0
San Antonio	701	119	132	29.17	29.88	−.02	83.2	+2.8	99	28	93	68	30	73	26	72	68	67	0.79	−2.3	8	6,371	se.	31	e.	3	11	17	2	4.4	0.0	0.0
Taylor	582	55	63	29.33	29.94	+.02	82.0	+2.0	97	28	92	64	30	72	27				1.81	−1.7	6	6,424	se.	36	ne.	30	5	21	4	5.4	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, June, 1923*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Ft.	Ft.	Ft.	Ft.	Ft.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	N	In.	In.		Miles.								0-10	In.	In.
Ohio Valley and Tennessee.							73.4	+0.5										71	4.62	+0.4										5.2		
Chattanooga	762	189	213	29.21	30.00	.00	75.2	−0.2	91	27	85	54	30	66	27	66	63	71	5.06	+0.8	16	4,676	sw.	44	s.	25	6	19	5	5.2	0.0	0.0
Knoxville	996	102	111	28.96	29.99	−.01	74.8	+1.0	92	21	85	50	30	66	27	66	63	74	4.26	+0.1	12	4,439	sw.	28	nw.	27	4	9	17	7.1	0.0	0.0
Memphis	399	76	97	29.55	29.96	−.01	77.0	−0.6	94	21	85	59	29	69	23	70	67	74	5.04	+0.7	11	5,104	s.	42	nw.	27	8	16	6	5.7	0.0	0.0
Nashville	546	168	191	29.43	30.00	+.01	74.9	−0.7	92	21	84	53	30	66	29	68	65	73	4.42	0.0	10	5,572	se.	62	nw.	27	9	10	11	5.4	0.0	0.0
Lexington	989	193	230	28.95	29.99	−.01	74.0	+0.8	96	22	82	50	29	66	22	...	...	...	3.55	−0.4	8	7,796	sw.	36	se.	18	16	7	7	4.2	0.0	0.0
Louisville	525	219	255	29.42	29.99	+.01	74.6	−0.1	98	22	84	54	29	66	27	66	62	68	6.28	+2.0	10	6,616	s.	39	n.	28	14	9	7	4.3	0.0	0.0
Evansville	431	139	175	29.52	29.98	+.01	75.4	+0.1	97	22	84	50	29	67	24	67	63	68	5.09	+0.9	9	6,580	sw.	48	n.	27	7	16	7	5.2	0.0	0.0
Indianapolis	822	194	230	29.11	29.98	+.01	72.8	+1.2	97	22	82	48	29	64	25	64	59	65	2.30	−2.0	9	7,172	sw.	36	w.	7	13	10	7	4.7	0.0	0.0
Royal Center	736	11	55	29.18	29.97	...	70.7	...	97	23	82	42	9	60	33	...	...	...	3.06	...	7	5,839	sw.	38	w.	7	5	16	9	5.9	0.0	0.0
Terre Haute	575	96	129	29.36	29.97	...	73.2	...	98	22	82	47	29	64	29	66	62	70	2.21	...	10	6,144	s.	28	nw.	28	8	14	8	4.7	0.0	0.0
Cincinnati	628	11	51	29.31	29.98	−.01	72.0	+0.8	95	22	82	47	30	62	29	...	63	72	3.18	−0.8	9	4,045	sw.	31	nw.	15	15	8	7	4.6	0.0	0.0
Columbus	824	179	222	29.12	29.98	−.01	71.9	+1.0	94	21	82	48	29	62	28	64	61	72	5.10	+1.6	12	5,716	w.	50	n.	24	8	15	7	5.4	0.0	0.0
Dayton	899	181	216	29.04	29.97	...	72.4	+0.2	97	22	82	49	30	63	25	64	60	69	3.69	−0.3	10	5,954	sw.	44	s.	6	17	8	5	4.1	0.0	0.0
Elkins	1,947	59	67	27.99	29.99	−.01	67.2	+0.6	93	22	79	41	10	56	34	61	59	82	6.94	+1.9	13	3,046	w.	21	ne.	24	6	12	12	6.0	0.0	0.0
Parkersburg	638	77	84	29.34	30.00	.00	73.0	+1.5	95	22	84	48	10	62	30	64	61	73	5.42	+0.8	11	3,033	nw.	31	nw.	24	12	10	8	5.4	0.0	0.0
Pittsburgh	842	353	410	29.08	29.96	−.03	71.6	+0.9	92	21	82	48	30	62	32	63	58	66	4.28	+0.4	12	6,138	w.	51	nw.	15	6	15	9	5.6	0.0	0.0
Lower Lake Region.							68.5	+1.7										67	2.87	−0.7										4.4		
Buffalo	767	247	280	29.10	29.92	−.05	64.8	+0.4	87	22	71	47	15	58	24	59	55	73	3.64	+0.5	9	11,037	w.	54	sw.	26	11	14	5	4.5	0.0	0.0
Canton	448	10	61	29.37	29.84	...	63.8	−2.0	87	20	74	35	15	53	33	...	...	...	4.49	+1.1	13	6,559	w.	36	sw.	26	18	8	4	3.1	0.0	0.0
Oswego	335	76	91	...	29.87	−.10	61.8	−3.0	88	19	70	42	13	53	27	...	...	...	2.86	−0.6	11	5,474	w.	27	w.	25	14	6	11	...	0.0	0.0
Rochester	523	86	102	29.36	29.92	−.05	67.4	+1.3	92	24	77	45	13	58	29	60	54	65	3.84	+0.7	11	6,093	w.	45	w.	25	12	10	8	4.9	0.0	0.0
Syracuse	597	97	113	29.27	29.91	−.06	66.9	0.0	90	19	76	46	13	58	31	...	...	...	2.90	−1.0	11	6,638	nw.	39	nw.	25	7	15	8	5.7	0.0	0.0
Erie	714	130	166	29.18	29.94	−.04	70.0	+3.8	90	21	78	49	13	62	24	62	57	64	1.17	−2.6	4	8,594	w.	48	w.	26	17	11	2	3.5	0.0	0.0
Cleveland	762	190	201	29.15	29.96	−.02	70.8	+3.7	91	25	78	52	8	63	27	63	58	64	1.49	−2.2	6	7,367	sw.	38	n.	28	11	13	6	4.8	0.0	0.0
Sandusky	629	62	70	29.29	29.96	−.02	71.8	+3.0	94	24	80	51	30	63	27	...	...	...	2.21	−1.6	9	5,133	sw.	33	nw.	8	10	13	7	5.2	0.0	0.0
Toledo	628	208	243	29.29	29.97	.00	72.4	+3.7	95	24	82	48	29	63	29	64	60	68	3.53	+0.2	8	8,680	sw.	46	sw.	7	19	7	4	3.3	0.0	0.0
Fort Wayne	856	113	124	29.07	29.98	...	72.0	+3.5	97	23	82	46	29	62	29	64	59	65	1.56	...	8	5,348	sw.	37	sw.	7	9	16	5	4.9	0.0	0.0
Detroit	730	218	258	29.18	29.95	−.02	71.3	+3.9	95	23	81	48	29	62	29	64	60	69	2.54	−1.4	11	6,502	sw.	38	w.	5	11	14	5	4.4	0.0	0.0
Upper Lake Region.							65.8	+3.1										71	2.54	−0.8										4.7		
Alpena	609	13	92	29.28	29.94	−.02	63.5	+3.1	91	24	73	38	15	54	37	57	53	72	3.10	−0.4	7	6,613	se.	36	n.	8	10	14	6	4.7	0.0	0.0
Escanaba	612	54	60	29.28	29.93	−.01	62.6	+2.0	92	24	71	41	8	54	30	58	55	77	3.20	−0.4	9	6,229	s.	37	nw.	26	12	11	7	4.5	0.0	0.0
Grand Haven	632	54	89	29.27	29.94	−.02	66.6	+2.9	93	23	75	45	7	58	32	61	57	72	2.84	+0.3	10	6,902	s.	44	w.	25	14	11	5	4.2	0.0	0.0
Grand Rapids	707	70	87	29.20	29.95	−.02	71.8	+3.7	98	23	83	45	29	61	32	63	58	65	1.67	−0.8	7	3,863	w.	25	w.	26	12	12	6	4.8	0.0	0.0
Houghton	684	62	99	29.20	29.92	−.02	63.4	+4.0	92	23	75	41	8	52	36	...	...	...	1.43	−2.1	9	6,475	e.	32	w.	25	8	13	9	5.5	0.0	0.0
Lansing	878	11	62	29.02	29.94	...	70.0	+2.6	95	23	82	41	29	58	35	62	59	73	2.90	−0.5	13	3,018	sw.	24	sw.	21	5	17	8	5.4	0.0	0.0
Ludington	637	60	66	29.26	29.95	...	62.1	...	85	23	70	42	7	54	27	58	56	79	1.24	...	7	6,121	s.	46	s.	25	17	8	5	3.3	0.0	0.0
Marquette	734	77	111	29.16	29.96	+.02	60.2	+1.7	94	23	70	40	6	50	37	54	50	71	3.10	−0.4	10	4,961	nw.	23	w.	19	7	12	11	5.9	0.0	0.0
Port Huron	638	70	120	29.26	29.94	−.03	68.4	+4.2	96	24	79	46	29	58	35	61	56	68	2.23	−1.0	10	6,443	sw.	40	nw.	5	11	17	2	3.9	0.0	0.0
Saginaw	641	69	77	29.26	29.94	...	70.0	...	96	23	82	42	29	58	35	63	59	71	1.53	−1.1	9	5,113	sw.	24	nw.	26	11	8	11	5.0	0.0	0.0
Sault Sainte Marie	614	11	52	29.26	29.95	−.01	61.3	+3.7	92	23	74	39	16	49	39	55	51	73	2.23	−0.5	6	4,417	w.	30	nw.	28	10	12	5	4.2	0.0	0.0
Chicago	823	140	310	29.09	29.96	.00	70.8	+2.6	96	25	79	51	29	63	31	62	57	64	1.70	−2.0	10	7,182	sw.	30	w.	12	16	10	4	3.8	0.0	0.0
Green Bay	617	109	144	29.27	29.92	−.03	68.9	+3.7	94	24	78	45	29	59	31	62	58	69	2.53	−1.0	13	6,768	s.	42	n.	7	10	12	8	5.6	0.0	0.0
Milwaukee	681	125	139	29.22	29.95	−.03	67.0	+3.1	90	18	76	49	8	58	29	60	56	69	3.23	−0.4	12	5,109	sw.	36	n.	25	13	10	7	4.7	0.0	0.0
Duluth	1,133	11	47	28.73	29.94	+.02	60.8	+3.6	85	24	71	41	7	50	35	56	53	77	3.89	−0.6	11	7,600	ne.	39	nw.	25	14	7	9	4.7	0.0	0.0
North Dakota.							66.9	+3.6										66	4.03	+0.3										5.4		
Moorhead	940	50	58	28.88	29.88	−.02	68.1	+3.7	92	17	79	42	28	57	30	61	56	67	6.73	+2.6	11	5,257	s.	40	nw.	25	8	13	9	5.7	0.0	0.0
Bismarck	1,674	8	57	28.14	29.89	+.02	66.6	+2.9	88	1	78	40	7	55	37	60	54	66	1.99	−1.6	14	7,354	se.	48	nw.	24	8	12	10	5.0	0.0	0.0
Devils Lake	1,482	11	44	28.32	29.87	−.01	67.0	+4.4	90	1	79	38	28	55	37	59	54	65	1.46	−2.1	8	6,390	se.	42	ne.	25	15	9	6	4.5	0.0	0.0
Ellendale	1,457	10	56	28.36	29.90	...	65.8	...	88	2	77	43	28	55	31	...	...	...	6.86	...	13	9,583	s.	56	ne.	20	7	10	13	6.1	0.0	0.0
Grand Forks	835	12	89	...	...	...	68.0	...	96	17	80	39	28	56	32	...	...	...	2.27	...	8	...	se.	60	sw.	17	14	9	7	...	0.0	0.0
Williston	1,878	41	48	27.87	29.81	−.05	66.0	+3.3	88	16	77	47	2	55	39	58	53	67	5.93	+2.4	12	6,175	se.	52	e.	2	4	18	8	5.8	0.0	0.0
Upper Mississippi Valley.							72.9	+1.9										71	4.03	−0.3										5.0		
Minneapolis	918	102	208	28.93	29.90	...	71.2	...	92	20	81	47	7	61	27	...	...	...	5.04	+1.0	13	7,192	s.	46	ne.	24	4	17	9	6.3	0.0	0.0
St. Paul	837	236	261	29.02	29.92	.00	70.0	+2.9	91	3	80	48	7	60	27	...	...	...	4.28	−0.1	13	7,488	se.	52	w.	17	12	16	2	4.1	0.0	0.0
La Crosse	714	11	48	29.17	29.92	−.01	71.6	+3.3	94	23	82	47	29	61	29	...	...	...	4.86	+0.4	10	2,709	se.	37	nw.	25	9	10	11	5.5	0.0	0.0
Madison	974	70	78	28.93	29.95	+.01	71.2	+3.0	96	24	80	49	29	62	27	64	60	70	3.05	−1.0	12	4,985	s.	30	sw.	2	8	11	11	5.6	0.0	0.0
Wausau	1,247	4	...	28.64	29.96	...	67.9	...	90	23	79	42	29	57	38	...	...	...	5.33	...	12	...	e.	...	...	...	14	9	7	4.6	0.0	0.0
Charles City	1,015	10	49	28.88	29.93	+.02	70.5	+1.7	94	24	81	45	29	60	26	65	61	74	3.65	−1.4	11	4,197	se.	27	w.	19	14	11	5	4.4	0.0	0.0
Davenport	606	71	79	29.30	29.95	+.01	73.6	+3.1	98	24	83	50	29	64	27	65	61	68	6.03	+1.9	12	4,750	s.	30	sw.	6	11	11	8	5.0	0.0	0.0
Des Moines	861	84	97	29.02	29.91	−.01	72.0	+1.4	96	25	80	50	29	64	25	65	62	75	4.95	0.0	11	4,808	s.	32	nw.	5	7	12	11	5.1	0.0	0.0
Dubuque	698	81	96	29.21	29.95	+.02	72.7	+3.3	97	24	82	48	29	63	33	64	60	68	3.66	−0.9	14	3,827	s.	34	nw.	25	11	9	10	5.3	0.0	0.0
Keokuk	614	64	78	29.28	29.94	.00	74.0	+1.5	96	23	83	51	29	65	24	66	62	69	3.17	−1.2	12	4,529	s.	29	sw.	4	8	16	6	5.6	0.0	0.0
Cairo	358	87	93	29.58	29.95	−.02	75.4	−0.9	93	26	84	54	29	67	25	68	65	75	3.30	−1.0	10	4,986	se.	44	sw.	6	8	11	11	5.4	0.0	0.0
Peoria	609	11	45	29.31	29.97	+.02	73.0	+2.1	97	24	83	45	29	63	27	66	62	72	2.09	−2.2	8	3,464	s.	21	sw.	6	20	7	3	3.3	0.0	0.0
Springfield, Ill	644	10	91	29.27	29.94	−.01	74.2	+2.0	99	23	84	51	29	65	26	66	63	71	2.74	−1.6	8	5,283	s.	29	n.	26	15	10	5	4.3	0.0	0.0
Hannibal	534	74	109	29.37	29.93	−.02	73.7	+1.2	96	23	83	51	29	65	27	...	...	...	5.25	+1.7	11	5,613	s.	48	sw.	4	11	13	6	4.9	0.0	0.0
St. Louis	567	265	303	29.35	29.94	−.01	75.2	+.04	95	23	83	55	29	67	22	67	63	71	4.33	−0.1	10	8,013	s.	38	sw.	18	10	11	9	5.1	0.0	0.0
Missouri Valley.							71.5	+0.7										74	5.50	+1.2										5.7		
Columbia, Mo	781	11	84	29.11	29.92	−.03	72.9	−1.6	93	23	82	51	29	64	26	...	...	...	6.31	+1.9	12	4,390	se.	27	w.	6	8	13	9	5.3	0.0	0.0
Kansas City	963	161	181	28.90	29.90	−.02	74.1	+1.1	96	25	82	56	29	66	21	67	64	73	6.51	+1.8	12	6,608	s.	52	ne.	15	10	16	4	4.7	0.0	0.0
St. Joseph	967	11	49	28.88	29.89	...	74.2	...	98	25	83	53	29	65	26	66	63	72	3.96	...	12	5,541	se.	43	nw.	27	12	12	6	4.7	0.0	0.0
Springfield, Mo	1,324	98	104	28.57	29.94	−.01	72.8	+0.5	91	27	81	53	29	65	29	68	66	85	6.10	+0.9	13	6,572	se.	52	nw.	27	15	10	5	4.2	0.0	0.0
Iola	984	11	50	28.87	29.89	−.04	75.2	+1.8	95	25	84	52	29	66	26	...	...	...	5.35	+0.6	9	4,412	s	30	w.	8	7	15	8	5.5	0.0	0.0
Topeka	987	92	107	...	...	...	74.0	+0.5	97	25	83	50	29	65	28	...	...	...	5.62	+0.8	10	7,059	s.	42	w.	27	9	10	11	5.4	0.0	0.0
Drexel	1,299	10	54	28.53	29.89	...	70.2	...	93	24	79	45	29	62	25	...	...	...	6.07	...	14	6,721	s.	40	ne.	27	3	12	15	7.1	0.0	0.0
Lincoln	1,189	11	84	28.64	29.88	−.02	72.1	+0.5	96	24	81	46	29	64	25	65	61	73	5.25	+0.9	12	7,127	se.	40	nw.	5	2	11	17	7.4	0.0	0.0
Omaha	1,105	115	122	28.74	29.90	−.01	72.4	+0.8	97	24	81	51	29	64	25	65	62	75	6.00	+1.0	12	5,115	se.	39	w.	27	5	15	10	5.9	0.0	0.0
Valentine	2,598	47	54	27.21	29.87	+.01	67.2	+0.3	96	24	78	46	12	56	32	60	55	68	3.48	−0.3	15	7,444	s.	44	sw.	18	6	15	9	5.6	0.0	0.0
Sioux City	1,135	94	164	28.72	29.90	.00	70.3	+0.8	95	24	78	44	29	62	27	64	61	74	5.14	+1.3	14	8,325	s.	42	se.	18	7	13	10	6.0	0.0	0.0
Huron	1,306	59	74	28.53	29.90	+.02	68.4	+2.2	99	24	78	45	28	58	33	62	59	74	4.14	+0.4	16	6,746	se.	38	se.	22	8	13	9	5.6	0.0	0.0
Pierre	1,572	70	75	28.21	29.84	−.03	68.7	+0.2	99	24	78	49	28	59	36	62	59	74	5.67	+2.6	13	6,369	se.	46	w.	22	11	6	13	5.4	0.0	0.0
Yankton	1,233	49	57	28.58	29.88	−.01	70.0	+1.1	95	24	79	44	29	61	28	...	...	...	6.49	+2.2	14	5,698	s.	33	s.	21	4	16	10	6.6	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, June, 1923*—Continued.

Districts and stations.	Elevation of instruments. Barometer above sea level.	Elevation of instruments. Thermometer above ground.	Elevation of instruments. Anemometer above ground.	Pressure. Station, reduced to mean of 24 hours.	Pressure. Sea level, reduced to mean of 24 hours.	Pressure. Departure from normal.	Temperature of the air. Mean max. + mean min. ÷ 2.	Temperature of the air. Departure from normal.	Temperature of the air. Maximum.	Temperature of the air. Date.	Temperature of the air. Mean maximum.	Temperature of the air. Minimum.	Temperature of the air. Date.	Temperature of the air. Mean minimum.	Temperature of the air. Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation. Total.	Precipitation. Departure from normal.	Precipitation. Days with 0.01, or more.	Wind. Total movement.	Wind. Prevailing direction.	Wind. Maximum velocity. Miles per hour.	Wind. Maximum velocity. Direction.	Wind. Maximum velocity. Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Ft.	Ft.	Ft.	Ft.	Ft.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	N	In.	In.		Miles.								0–10	In.	In.
Northern Slope.							**61.6**	**0.0**										**64**	**3.06**	**+0.8**										**5.1**		
Billings	3,140	5	......	......	......	......	63.2	......	93	12	79	36	2	47	44	......	......	......	2.68	......	11	......	nw.	......	......	......	8	8	14	......	0.0	0.0
Havre	2,505	11	44	27.24	29.82	−.03	63.8	+1.8	96	12	76	44	2	52	37	56	50	68	5.89	+3.1	14	5,272	sw.	56	s.	12	9	14	7	5.1	0.0	0.0
Helena	4,110	87	112	25.72	29.84	−.04	58.9	−0.3	91	12	70	35	14	47	36	49	41	59	3.24	+1.1	14	5,753	sw.	36	sw.	26	4	9	17	6.8	0.0	0.0
Kalispell	2,973	48	56	26.83	29.84	−.05	58.1	−0.7	85	30	68	37	14	48	32	50	44	67	1.49	−0.2	11	3,882	nw.	43	sw.	10	6	12	12	6.0	0.0	0.0
Miles City	2,371	48	55	27.34	29.84	−.01	68.2	+2.2	92	16	79	50	2	58	36	58	52	62	1.84	−0.9	16	5,255	se.	36	s.	13	13	11	6	4.3	0.0	0.0
Rapid City	3,259	50	58	26.53	29.87	+.02	64.8	+1.0	95	24	76	46	7	54	36	56	49	60	5.62	+2.0	16	6,336	se.	46	sw.	26	9	11	10	5.2	0.0	0.0
Cheyenne	6,088	84	101	23.98	29.83	−.01	59.4	−1.0	86	24	70	42	1	48	35	51	45	66	2.32	+0.8	13	8,303	s.	50	s.	16	12	9	9	4.5	0.0	0.0
Lander	5,372	60	68	24.58	29.82	−.03	60.2	−1.1	88	30	74	37	2	46	39	49	41	54	0.86	−0.2	6	4,472	sw.	46	sw.	22	13	13	4	4.2	0.0	0.0
Sheridan	3,790	10	47	26.04	29.87	......	61.8	......	86	12	75	39	2	48	40	54	48	64	2.11	......	11	4,338	se.	39	se.	15	14	13	3	4.3	0.0	0.0
Yellowstone Park	6,200	11	48	23.85	29.87	+.01	52.0	−4.0	80	12	65	29	14	39	42	43	36	61	2.10	+0.5	20	5,234	s.	36	s.	24	6	16	8	5.9	0.1	0.0
North Platte	2,821	11	51	27.02	29.89	+.03	69.2	+1.7	94	24	80	48	29	59	29	61	58	74	4.15	+0.9	10	5,752	s.	33	sw.	14	14	9	7	5.1	0.0	0.0
Middle Slope.							**71.8**	**+0.1**										**67**	**5.46**	**+2.3**										**4.6**		
Denver	5,292	106	113	24.68	29.83	−.01	65.4	−0.9	94	24	77	48	11	54	37	53	44	54	3.55	+2.1	11	5,548	s.	34	nw.	4	13	14	3	4.0	0.0	0.0
Pueblo	4,685	80	86	25.22	29.79	−.04	69.5	+0.5	97	24	83	49	9	56	43	54	43	49	0.91	−0.6	9	5,301	e.	42	s.	16	12	15	3	3.9	0.0	0.0
Concordia	1,392	50	58	28.43	29.86	−.04	73.0	+0.3	94	25	81	50	29	65	24	66	64	77	7.32	+2.4	16	5,590	s.	30	nw.	6	5	19	6	5.7	0.0	0.0
Dodge City	2,509	11	51	27.34	29.89	+.02	71.8	−0.7	93	24	82	50	29	62	30	64	61	73	2.96	−0.4	14	8,150	se.	45	ne.	29	15	10	5	4.1	0.0	0.0
Wichita	1,358	139	158	28.46	29.86	−.05	74.3	0.0	96	25	83	54	29	66	27	67	64	75	14.43	+9.7	13	8,371	s.	60	se.	14	8	14	8	4.9	0.0	0.0
Broken Arrow	765	11	52	29.10	29.92	......	75.9	......	97	27	84	55	29	68	23	......	......	......	6.43	......	10	8,506	se.	58	n.	15	8	13	9	5.2	0.0	0.0
Muskogee	652	4	......	......	......	......	78.5	......	98	26	89	55	29	68	27	......	......	......	4.24	......	7	......	s.	......	......	......	14	13	3	......	0.0	0.0
Oklahoma City	1,214	10	47	28.64	29.89	−.02	76.9	+1.2	100	27	86	54	29	68	27	68	65	72	3.62	+0.6	5	7,996	s.	28	s.	1	12	14	4	4.4	0.0	0.0
Southern Slope.							**77.9**	**+0.7**										**59**	**4.06**	**+1.5**										**4.0**		
Abilene	1,738	10	52	28.09	29.85	−.03	79.4	+1.2	100	27	90	60	9	69	28	68	62	62	3.81	+0.6	9	8,322	se.	40	sw.	1	10	14	6	4.5	0.0	0.0
Amarillo	3,676	10	49	26.22	29.86	+.01	72.4	+0.4	95	14	84	53	8	61	36	63	58	67	9.76	+6.8	11	8,947	se.	34	e.	7	24	5	1	3.0	0.0	0.0
Del Rio	944	64	71	28.88	29.84	−.01	82.3	+0.2	99	28	91	65	2	73	24	......	......	......	1.51	−0.9	6	8,261	se.	40	sw.	1	12	7	11	5.2	0.0	0.0
Roswell	3,566	75	85	26.25	29.75	−.05	77.4	+1.1	101	27	91	52	1	63	42	60	47	47	1.18	−0.6	3	8,009	s.	52	w.	8	16	12	2	3.2	0.0	0.0
Southern plateau.							**71.6**	**−2.8**										**31**	**0.07**	**−0.3**										**1.3**		
El Paso	3,762	110	133	26.05	29.68	−.07	81.4	+1.8	104	30	95	60	9	68	34	57	37	26	0.09	−0.5	1	6,794	e.	42	ne.	28	27	1	2	1.5	0.0	0.0
Santa Fe	7,013	38	53	23.24	29.72	−.09	65.2	+0.4	88	30	78	42	1	52	33	49	34	37	0.24	−0.8	4	5,618	se.	28	s.	16	21	6	3	2.4	0.0	0.0
Flagstaff	6,908	10	59	23.31	29.76	−.02	54.7	−4.6	89	30	73	23	17	36	48	39	......	34	T.	......	0	......	......	38	sw.	16	27	3	0	......	0.0	0.0
Phoenix	1,108	11	81	28.59	29.71	−.03	80.8	−3.6	112	29	98	54	17	63	44	57	36	24	0.00	−0.1	0	3,883	w.	23	w.	3	30	0	0	0.3	0.0	0.0
Yuma	141	9	54	29.57	29.71	−.03	80.2	−4.5	114	29	98	56	1	62	46	60	44	36	0.00	0.0	0	3,445	sw.	29	nw.	15	29	1	0	0.3	0.0	0.0
Independence	3,957	9	41	25.84	29.81	+.03	67.0	−6.4	100	29	82	40	16	52	42	48	31	29	T.	−0.1	0	5,521	nw.	39	w.	12	22	8	0	2.0	0.0	0.0
Middle Plateau.							**61.8**	**−3.6**										**41**	**0.90**	**+0.4**										**3.6**		
Reno	4,532	74	81	25.38	29.84	−.02	57.4	−3.6	94	30	72	30	13	43	45	45	34	51	0.99	+0.8	5	5,445	w.	36	w.	23	13	16	1	3.7	T.	0.0
Tonopah	6,090	12	20	23.95	29.76	......	58.8	......	93	30	71	31	13	47	32	44	29	41	0.16	−0.3	4	5,915	nw.	38	nw.	12	14	10	6	4.0	T.	0.0
Winnemucca	4,344	18	56	25.52	29.87	−.01	57.8	−5.0	92	30	71	29	1	44	43	46	37	57	2.59	+2.0	10	4,299	sw.	29	sw.	11	13	8	9	4.8	0.0	0.0
Modena	5,479	10	43	24.52	29.77	−.05	59.1	−4.1	97	30	76	22	1	42	49	42	22	29	0.24	−0.2	2	8,697	sw.	54	s.	12	20	7	3	2.9	0.0	0.0
Salt Lake City	4,360	163	203	25.51	29.81	−.04	64.2	−3.2	92	30	75	41	1	53	32	50	38	42	1.39	+0.6	8	5,952	nw.	38	sw.	21	18	5	7	3.5	0.0	0.0
Grand Junction	4,602	60	68	25.26	29.76	−.07	70.6	−2.0	96	30	86	39	1	56	37	50	29	25	0.02	−0.4	1	5,818	se.	42	sw.	16	20	7	3	2.8	0.0	0.0
Northern Plateau.							**61.6**	**−3.2**										**61**	**2.38**	**+1.2**										**5.9**		
Baker	3,471	48	53	26.36	29.91	−.04	56.3	−2.3	88	29	67	35	13	46	36	49	44	70	2.54	+1.3	15	3,796	se.	28	nw.	11	5	10	15	6.5	0.0	0.0
Boise	2,739	78	86	27.05	29.88	−.03	62.6	−2.7	94	30	74	41	2	51	35	52	45	60	2.05	+1.2	14	3,320	w.	29	w.	12	10	9	11	5.1	0.0	0.0
Lewiston	757	40	48	29.06	29.86	−.08	64.2	−4.9	98	30	76	42	14	53	42	......	......	......	2.10	+1.1	10	2,251	e.	22	nw.	11	6	7	17	6.6	0.0	0.0
Pocatello	4,477	60	68	25.38	29.84	−.03	59.5	−4.7	91	30	73	36	14	46	39	48	39	54	1.68	+0.7	10	5,082	se.	36	s.	12	8	13	9	5.4	0.0	0.0
Spokane	1,929	101	110	27.86	29.88	−.06	61.7	−1.1	91	30	72	42	14	51	35	53	47	65	3.03	+1.4	9	4,091	sw.	22	sw.	1	5	8	17	6.7	0.0	0.0
Walla Walla	991	57	65	28.82	29.88	−.08	65.0	−3.2	97	29	75	46	13	55	36	55	47	57	2.89	+1.7	9	3,537	s.	25	nw.	9	11	10	9	5.1	0.0	0.0
North Pacific Coast Region.							**59.6**	**+0.8**										**77**	**0.86**	**−1.1**										**6.1**		
North Head	211	11	56	29.76	29.98	−.01	55.6	+0.6	71	5	59	48	1	52	19	53	51	86	0.96	−0.8	11	9,296	nw.	40	nw	14	7	11	12	6.1	0.0	0.0
Port Angeles	29	8	53	......	29.99	......	56.0	......	82	28	64	40	12	48	34	......	......	......	0.79	−0.5	7	4,985	sw.	27	w.	10	7	11	12	......	0.0	0.0
Seattle	125	215	250	29.84	29.97	+.03	60.6	+0.5	85	6	69	47	13	52	28	53	48	67	1.01	−0.5	7	5,576	s.	36	s.	10	8	8	14	6.2	0.0	0.0
Tacoma	213	113	120	29.73	29.95	+.08	61.6	+2.2	84	6	71	47	13	53	27	......	......	......	0.29	−1.8	5	5,675	w.	28	n.	28	5	15	10	6.0	0.0	0.0
Tatoosh Island	86	9	57	29.88	29.97	−.05	54.0	+1.0	72	5	58	45	14	50	22	53	52	95	0.57	−3.6	6	6,585	sw.	31	sw.	7	2	10	18	7.7	0.0	0.0
Yakima	1,071	5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Medford	1,425	4	......	......	......	......	64.0	......	98	30	80	39	2	48	45	......	......	......	0.45	......	7	......	nw.	......	......	......	7	5	18	......	0.0	0.0
Portland, Oreg.	153	68	106	29.79	29.95	−.09	62.5	+0.1	94	28	72	48	14	53	32	55	50	70	1.19	−0.6	10	3,701	nw.	21	w.	12	6	10	14	6.5	0.0	0.0
Roseburg	510	9	57	29.42	29.97	−.06	63.0	+0.5	93	28	76	39	2	50	39	54	48	66	1.22	+0.2	10	2,360	nw.	14	sw.	11	10	17	3	4.0	0.0	0.0
Middle Pacific Coast Region.							**59.8**	**−2.8**										**68**	**0.68**	**+0.3**										**4.3**		
Eureka	62	73	89	29.96	30.03	−.02	54.3	−0.3	62	28	58	44	22	50	14	51	49	86	1.07	0.0	10	5,051	n.	26	sw.	4	2	15	13	6.7	0.0	0.0
Point Reyes	490	7	18	29.41	29.93	......	51.6	−1.2	58	17	55	45	12	48	10	......	......	......	0.18	......	3	18,056	nw.	66	nw.	12	9	8	13	5.7	0.0	0.0
Red Bluff	332	50	56	29.51	29.86	−.02	69.1	−5.7	102	30	82	46	1	56	39	56	45	49	2.06	+1.6	7	3,808	se.	28	w.	11	24	5	1	2.5	0.0	0.0
Sacramento	69	106	117	29.81	29.88	−.01	65.9	−3.5	97	30	79	48	1	53	42	54	46	57	0.09	−0.1	1	6,599	s.	25	sw.	20	24	5	1	2.3	0.0	0.0
San Francisco	155	208	243	29.78	29.95	−.01	57.2	−1.3	69	24	63	49	3	51	18	47	49	79	0.06	−0.1	3	8,356	w.	36	w.	11	12	12	6	4.4	0.0	0.0
San Jose	141	12	110	29.81	29.96	......	60.4	−4.6	80	29	72	42	2	49	35	......	......	......	0.10	0.0	2	4,810	nw.	28	nw.	11	10	14	6	4.4	0.0	0.0
South Pacific Coast Region.							**63.6**	**−3.0**										**68**	**0.02**	**0.0**										**3.0**		
Fresno	327	89	98	29.52	29.87	+.02	69.4	−6.4	100	30	84	49	22	55	37	55	43	47	T.	−0.1	0	7,119	nw.	33	nw.	11	24	3	3	1.9	0.0	0.0
Los Angeles	338	159	191	29.54	29.90	.00	63.6	−2.8	87	29	72	51	16	55	27	57	53	74	0.02	0.0	1	4,008	sw.	17	sw.	15	18	8	4	3.4	0.0	0.0
San Diego	87	62	70	29.80	29.89	−.03	62.3	−1.6	73	29	67	53	1	58	15	57	54	77	0.04	0.0	2	5,039	w.	18	w.	14	14	10	6	3.9	0.0	0.0
San Luis Obispo	201	32	40	29.74	29.96	+.01	59.2	−1.2	83	9	70	40	1	49	36	51	46	72	0.04	−0.1	1	3,758	nw.	21	w.	12	21	7	2	2.6	0.0	0.0
West Indies.																																
San Juan, P. R.	82	9	54	29.96	30.05	......	78.2	......	86	1	83	70	8	74	12	......	......	......	3.04	−2.8	17	10,028	e.	48	e.	8	6	16	8	5.8	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.71	29.83	.00	80.2	+0.2	90	10	86	72	7	74	18	75	74	88	5.59	−1.8	15	3,698	nw.	38	se.	10	0	9	21	7.8	0.0	0.0
Colon	36	7	97	29.80	29.83	−.01	81.6	+1.4	91	5	87	73	27	76	15	77	76	85	15.17	+1.8	25	4,960	n.	30	w.	11	0	9	21	8.2	0.0	0.0
Alaska.																																
Juneau	80	11	54	29.88	29.97	......	54.6	......	80	6	64	40	12	45	33	51	46	70	1.43	......	9	4,615	s.	32	nw.	22	7	6	17	6.9	0.0	0.0

TABLE II.—*Data furnished by the Canadian Meteorological Service, June, 1923.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	In.	In.	In.	° F.	° F.	° F.	° F.	° F.	° F.	In.	In.	In.
St. Johns, N. F.	125	29.55	29.69	−.22	51.1	−0.5	59.8	42.5	78	34	3.56	−0.04	0.0
Sydney, C. B. I.	48	29.74	29.79	−.16	53.6	−1.8	65.0	42.3	80	33	1.36	−1.87	0.0
Halifax, N. S.	88	29.69	29.79	−.16	57.5	−0.2	67.8	47.2	86	35	4.36	+0.60	0.0
Yarmouth, N. S.	65	29.72	29.79	−.16	53.8	−1.2	61.8	45.9	75	38	2.93	+0.17	0.0
Charlottetown, P. E. I.	38	29.71	29.75	−.17	55.5	−1.9	63.9	47.1	80	37	1.62	−1.05	0.0
Chatham, N. B.	28	29.66	29.69	−.20	57.6	−2.4	70.9	44.3	95	32	0.96	−2.50	0.0
Father Point, Que.	20	29.75	29.77	−.10	49.8	−3.2	60.1	39.5	69	29	4.80	+1.82	0.0
Quebec, Que.	296	29.49	29.80	−.12	62.4	+1.2	72.5	52.4	88	40	2.30	−1.35	0.0
Montreal, Que.	187	29.61	29.81	−.13	65.6	+0.7	74.8	56.3	91	44	3.22	−0.31	0.0
Stonecliffe, Ont.	489												
Ottawa, Ont.	236	29.58	29.84	−.10	66.3	+1.0	77.7	54.9	95	40	5.61	+2.69	0.0
Kingston, Ont.	285	29.57	29.88	−.09	62.9	−0.5	71.0	54.8	84	40	2.34	−0.09	0.0
Toronto, Ont.	379	29.50	29.89	−.08	66.6	+3.2	77.0	56.1	96	44	4.23	+1.43	0.0
Cochrane, Ont.	930												
White River, Ont.	1,244	28.60	29.89	−.05	59.1	+0.4	73.9	44.3	89	27	2.11	−0.11	0.0
Port Stanley, Ont.	592												
Southampton, Ont.	656	29.22			61.2	+0.8	70.7	51.8	87	38	1.51	−0.84	0.0
Parry Sound, Ont.	688	29.21	29.89	−.07	62.6	+0.9	74.5	50.7	90	37	1.98	−0.44	0.0
Port Arthur, Ont.	644	29.25	29.96	+.02	61.9	+5.5	72.3	51.5	89	40	2.02	−0.71	0.0
Winnipeg, Man.	760	29.05	29.86	−.03	67.6	+5.4	80.7	54.5	93	41	1.47	−1.82	0.0
Minnedosa, Man.	1,690	28.11	29.89	.00	63.6	+4.0	74.5	52.6	86	38	3.66	+0.66	0.0
Le Pas, Man.	860				59.8		72.9	46.7	91	29	1.80		0.0
Qu'Appelle, Sask.	2,115	27.61	29.81	−.06	62.6	+2.7	73.7	51.5	90	42	8.22	+4.80	0.0
Medicine Hat, Alb.	2,144	27.52	29.72	−.13	66.6	+4.6	79.3	54.0	98	42	5.35	+2.59	0.0
Moose Jaw, Sask.	1,759				64.0		74.9	53.0	93	43	5.03		0.0
Swift Current, Sask.	2,392	27.29	29.86	−.01	63.5	+3.5	75.6	51.4	90	42	6.82	+4.15	0.0
Calgary, Alb.	3,428												
Banff, Alb.	4,521	25.34	29.84	.00	53.8	+2.3	66.5	41.0	80	32	5.63	+2.30	0.0
Edmonton, Alb.	2,150	27.56	29.80	−.04	59.9	+3.0	71.2	48.6	86	43	4.07	+1.21	0.0
Prince Albert, Sask.	1,450	28.34	29.89	+.02	61.2	+3.5	71.7	50.8	88	41	3.69	+1.18	0.0
Battleford, Sask.	1,592	28.12	29.83	−.03	62.6	+3.1	72.8	52.5	87	43	6.08	+2.77	0.0
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.69	29.94	−.07	57.3	+1.0	65.0	49.6	86	47	0.38	−0.82	0.0
Barkerville, B. C.	4,180												
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

LATE REPORTS FOR MAY, 1923.

Banff, Alb.	4,521	25.33	29.88	.00	45.9	−1.1	59.1	32.6	73	24	3.41	+1.37	2.7
Medicine Hat, Alb.	2,144	27.56	29.80	−.09	57.7	+3.6	72.3	43.2	93	23	1.09	−0.22	0.0
Edmonton, Alb.	2,150	27.57	29.84	−.05	50.5	−0.3	64.9	36.2	81	24	1.71	+0.16	0.0

LATE REPORT FOR APRIL, 1923.

Edmonton, Alb.	2,150	27.58	29.88	−.01	40.1	+0.2	53.2	27.1	82	5	0.36	−0.54	1.0

SEISMOLOGICAL REPORTS FOR JUNE, 1923.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, August 3, 1923.]

TABLE 1.—*Noninstrumental earthquake reports, June, 1923.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
1923.	H. m.	CALIFORNIA.	° ′	° ′			Sec.			
June 4	5 ..	Brawley	32 59	115 40	3	1		Yes	Felt by many	M. D. Witter.
16	20 40	Paso Robles	35 40	120 30	4	1	15-20	None		E. J. Nye.
25	13 21	San Luis Obispo	35 13	120 45	2	1	2	....do	Felt by several	J. E. Hissong.
30	0 22	Los Angeles	34 03	118 15	3	1	Few.	....do	....do	F. M. Young.
	0 26	....do	34 03	118 15	2	1	1-2	....do	....do	A. W. Pugh.
		UTAH.								
9	2 37	Richmond	42 00	111 50	2	1	15	....do	Felt by many	J. R. Thomson.

TABLE 2.—*Instrumental seismological reports, June, 1923.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols and description of stations, see REVIEW for January, 1923.]

ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 1		*O*	17 23 47				6,860	
		eP_E	17 35 13	12				
		eP_N	17 34 07	8				
		S_E	17 42 29	16				
		S_N	17 42 44	14				
		$SR1_N$	17 47 57	10				
		e_E	17 51 20					
		e_N	17 51 13					
		$L1_E$	17 56 10	15				
		$L2_E$	18 01 58					
		L_N	18 00 14					
		$L3_E$	18 06 48	13				
		M_E	18 07 37	13	*100			
		M_N	18 03 56	15		*100		
		F_E	18 31 ..					
		F_N	18 36 ..					
18		*O*	8 16 28				8,620	No definite M.
		P_E	8 28 21	11				
		S_E	8 38 19					
		S_N	8 38 12					
		PS_E	8 39 25					
		$L1_E$	8 50 39	27				
		L_N	8 50 20	26				
		$L2_E$	8 53 29					
		$L3_E$	8 59 07					
		F	9 16 ..					
19		*O*	22 43 53				1,090	Motion very irregular.
		P_E	22 46 15					
		P_N	22 46 23					
		S_E	22 48 21					
		S_N	22 48 12					
		L_E	22 49 02					
		L_N	22 48 47	7				
		M_E	22 51 12	10	*600			
		M_N	22 49 59	16		*1,000		
		C_N	22 56 ..					
		F	23 24 ..					
20		e_E	6 08 06	1				Local tremors.
		e_E	6 08 29	1				
		i_N	6 08 18	2				
		L	6 08 43	8				
		M_E	6 08 47	8	*100			
		F	6 12 ..					
22		P_N	3 47 10					Tremors of 2 seconds period superimposed on L waves. Local.
		S_E	3 47 20					
		S_N	3 47 32					
		L_E	3 47 37					
		L_N	3 47 42					
		M_E	3 47 55	8	*400			
		M_N	3 47 45	9		*200		
		F_E	3 53 ..					
		F_N	3 55 ..					
22		*O*	7 00 31				4,280	
		P_E	7 08 09	12				
		P_N	7 08 30					
		S_E	7 14 12	15				
		$L1_E$	7 19 51					
		$L2_E$	7 22 41					
		$L3_E$	7 30 54					
		$L1_N$	7 30 32	26				
		$L2_N$	7 34 24	24				
		$M1_E$	7 34 53	24	*300			
		$M2_E$	7 39 50	18	*500			
		M_N	7 35 19	23		*400		
		F_E	7 52 ..					
		F_N	8 04 ..					

ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 18		*O*	8 16 14				8,550	Records very faint.
		P_E	8 28 04					
		P_N	8 28 08					
		e_E	8 28 39	4				
		S	8 37 52					
		e_E	8 38 12	6				
		e_E	8 41 18					
		L_E	8 55 29	17	*100			
		F	9 30 ..					

*Trace amplitude.

58420—23——4

CALIFORNIA. *Theosophical University, Point Loma.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 2			15 00 00		50	50		Tremors during preceding 24 hours.
20					50	100		
21					50	100		
22					50	50		
25					100	100		
30					50	50		

COLORADO. *Regis College, Denver.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 19		L	22 01 ..					Very small; P not discernible.
		M	22 03 ..	5-8	*1500	*1000		
		F	22 10 ..					

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 1		P	17 38 34					
		PR1	17 42 26					
		S	17 48 52					
		eL	18 13 ..					
		L	18 28 ..	15				
		F	19 15 ..					
1		S	20 39 55					
		eL	21 09 ..					
		F	21 30 ..					
6		e	23 15 30					
		S	23 17 06					
		F	23 30 ..					
18		P?	8 30 11				8,800	
		S	8 40 11					
		eL	9 00 ..					
		L	9 03 30	25				
		F	9 25 *ca*					
19		iP	22 52 32				5,500	
		S	22 59 39					
		eL	23 07 28					
		M	23 10 ..		*5000			
		F	23 40 *ca*					
22		e	4 04 12					
		F	4 15 *ca*					
22		P	7 04 38					
		S	7 11 44					
		eL	7 45 ..					
		L	7 48 ..	28				
		L	7 54 ..	20				
		F	8 20 *ca*					

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 1		*O*	17 24 31				6,100	Activity continues to next quake; EW record obscured by overlap.
		P_N	17 34 08					
		S_N	17 41 49	18		33		
		$SR1_N$	17 45 22	20				
		$SR2_N$	17 47 00	24				
		$L1_N$	17 48 22	10				
		$L2_N$	17 49 07	15				
		M_N	17 54 40	9		34		
		C_N	18 03 ..	11				
1		S_N(?)	20 32 47	20		19		EW record obscured by overlap; apparently same origin as preceding quake
		$L1_N$	20 39 12					
		$L2_N$	20 40 20					
		$L3_N$	20 40 37	10				
		M_N	20 41 33	14		35		
		C	20 51 ..	10				
		F	21 25 ..	10				
2		i_E	14 35 23					
		e_N	14 35 34					
		M_E	14 35 30	15	10			
		M_N	14 39 50	9		4		
		F_E	14 41 ..					
		F_N	14 44 ..					

*Trace amplitude.

TABLE 2.—*Instrumental seismological reports, June, 1923*—Continued.

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu*—Cont'd.

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 4		i_N	21 42 57					EW record obscured by overlap.
		e_N	21 43 50	27		10		
		F_N	21 54 ..					
5		e_N	6 39 57					
		e_E	6 42 38					
		e_N	6 42 33					
		L_N	6 44 27	8				
		M_E	6 43 57	8	5			
		M_N	6 45 05	8		6		
		F	6 49 ..					
6		e_E	18 00 35	11	8			
		e_N	18 01 00	10		8		
		F_E	18 03 ..					
		F_N	18 10 ..					
18		*O*	8 16 30				4,210	L_E indeterminate.
		P_E	8 24 07					
		P_N	8 24 03	10		14		
		PR_N	8 25 26					
		e_N	8 27 05	11		15		
		S_E	8 30 02					
		iS_N	8 30 13	10		40		
		iPS_E	8 31 00					
		iPS_N	8 31 07					
		$iSR1_E$	8 33 27					
		$iSR1_N$	8 33 22					
		eL_N	8 35 28					
		M_E	8 33 30	22	186			
		M_N	8 43 35	16		47		
		F_E	9 40 ..					
		F_N	9 30 ..					
19		*O*	22 42 38				5,030	
		S_E	22 58 03					
		S_N	22 57 52					
		SR1	23 01 08					
		$SR2_E$	23 01 52					
		$L1_E$	23 03 40					
		$L1_N$	23 03 03					
		$L2_N$	23 05 22	11				
		M_E	23 03 50	10	27			
		M_N	23 07 40	8		14		
		F_E	23 51 ..					
20		F_N	00 05 ..					
22		*O*	7 00 28				4,880	
		P_E	7 09 00					
		P_N	7 08 48					
		$PR1_E$	7 10 18					
		S_E	7 15 42					
		S_N	7 15 24					
		L_E	7 22 25					
		L_N	7 22 40					
		M_E	7 32 00	26	184			
		M_N	7 32 22	19		100		
		F	8 36 ..					
22		*O*	20 57 20				2,820	
		P_E	21 03 05					
		P_N	21 03 00					
		S_N	21 07 30					
		L_E	21 09 30	20	10			
		L_N	21 09 56	30		22		
		F	21 25 ..					
26		e_E	1 19 20	12	5			Nothing on NS.
		F_E	1 21 ..					

ILLINOIS. *U. S. Weather Bureau, Chicago.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 1		P	17 37 50				9,300	
		PR1	17 42 00					
		S	17 48 15					
		SR1	17 54 44					
		L	18 06 40					
		L	18 16 ..	20				
		L	18 24 ..	15				
		F						Lost in next quake.
1		P	20 28 57					
		PR1	20 32 30					
		S	20 39 14					
		SR1	20 45 42					
		L	20 57 40					
		L	21 05 ..	20				
		L	21 12 ..	15				
		F						Off sheet.
2		P	1 11 15				9,000	
		S	1 21 27					
		eL	1 57 ..					
		L	2 13 ..	15				
		F	2 45 *ca*					
5		e	6 28 50					
		eL?	6 34 30					
		F	7 *ca* ..					
6		e	1 40 50					Feeble; may not be seismic.
		F	2 00 ..					
6		eL	20 05 ..	20				
		L	20 18 ..	15				
		F	20 35 *ca*					

*Trace amplitude.

ILLINOIS. *U. S. Weather Bureau, Chicago*—Continued.

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 6		e	23 08 48					
		S	23 12 40					
		F	23 40 ..					
14		e	6 15 23					
		eL	6 18 36	15				
		F	6 40 *ca*					
18		P	8 30 18				8,600	
		PR1	8 34 24					
		iS	8 40 06					
		SR1	8 47 52					
		eL	8 57 40					
		L	9 00 ..	25				
		L	9 08 ..	15				
		F	10 40 *ca*					
19								Quake not measurable, due to crowding of lines.
22		P?	4 00 10					
		S	4 04 00					
		F	4 30 ..					
22		P	7 04 21					
		S	7 12 00				6,100	
		L	7 19 44					
		L	7 35 ..	30				
		L	7 49 ..	22				
		L	8 00 ..	18				
		L	8 10 ..	15				
		F	10 *ca* ..					
22		e	21 15 ..					
		eL	21 42 ..					
		L	21 43 ..	18				
		F	22 20 *ca*					

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 1		eS_N(?)	17 51 27					
		eS_E(?)	17 53 31					
		$L1_N$	18 14 06					
		$L1_E$	18 17 30					
		$L2_N$	18 21 25					
		M_E	18 23 15	16	*100			
		M_N	18 26 43	17		*100		
		F_E	18 42 ..					
		F_N	18 48 ..					
19		*O*	22 43 27				5,580	Motion very irregular.
		P_N	22 52 32					
		S_E	22 59 46					
		$L1_E$	23 06 39					
		$L2_E$	23 08 33					
		$L1_N$	23 08 47	10				
		$L2_N$	23 09 29	5				
		M_E	23 10 39	9	*300			
		M_N	23 10 22	5		*200		
		F_E	23 22 ..					
		F_N	23 25 ..	7				
22		e_E	7 49 19					
		e_N	7 47 02	23				
		L_N	7 58 13	24				
		M_N	8 00 15	14		*100		
		F_E	8 03 ..					
		F_N	8 08 ..					

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 10		e_E	1 32 28					Local tremors.
		e_N	1 32 21					
		L	1 32 48	1	10	10		
		F	1 37 ..					

VERMONT. *U. S. Weather Bureau, Northfield.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 1		P	17 39 18					
		S	17 49 14					
		eL	18 10 ..					
		L	18 15 ..	20				
		L	18 26 ..	16				
		F	19 *ca* ..					
1		eL	21 08 ..					
		F	21 20 ..					
18		e	8 40 ..					
		F	9 00 *ca*					
19		P?	22 50 30					
		S?	22 58 56					
		eL	23 07 ..					
		M_E	23 09 ..		*31000			
		F	23 30 *ca*					
22		e	4 06 30					
		F	4 10 *ca*					

*Trace amplitude.

TABLE 2.—*Instrumental seismological reports, June, 1923*—Continued.

CANADA. *Dominion Observatory, Ottawa.*

INSTRUMENTS—DETERMINED CONSTANTS.

Instrument.	T_0—	r	V	ε	Comp.	l	Determined.
I	5.5		120	2:1	N. S.		Apr. 4, 1923
II	5.3		120	18:1	E. W.		May 30, 1923
17	12.0		250	20:1	E. W.		May 30, 1923
23	12.0		250	20:1	E. W.		May 30, 1923
D	37.2			13:10	E. W.		Feb. 7, 1923
D	36.1			13:10	N. S.		Feb. 7, 1923
W	6.0	6 mm.	160	20:1	V.		May 30, 1923

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 1		*O*	17 25 31				9,320	
		P	17 38 00					
		PR1.	17 41 46					
		S	17 48 26					
		i	17 48 49					
		i	17 50 00					
		SR1	17 54 30					
		L	18 09 ..					
		L	18 14 30	23				
		M	18 19 30					
		M	18 24 30					
		M	18 28 30					
		L	18 30 *to*					
			20 00 ..					
		F						Lost in next quake.
1		P						Lost in preceding quake.
		S	20 39 23					
		L	20 46 ..					
		L	20 55 ..					
		L	21 02 ..	23				
		M	21 13 30					
		L	21 20 *to*					
			22 40 ..					
		F	23 26 ..					
2		e	1 20 30					
		e	1 28 ..					
		eL	1 36 ..					
		L	2 04 ..					
		F	3 30 *ca*					
2		eL	5 53 30					
		F	6 03 ..					
2		eL_M	13 39 ..					
		L_M	13 43 30					
		F	14 26 *ca*					
2		e?	14 43 42					
		e	14 54 ..					
		L	15 14 30					
		F	16 00 *ca*					
2		eL	23 58 ..					
3		F	0 10 *ca*					
3		eL	12 23 ..					
		L	12 30 30					
		L	12 35 *to*					
			12 50 ..					
		F	13 00 *ca*					
4		e?	(21 20)					Small traces only.
		eL	(21 40)					
		L	21 51 *to*					
			21 56 ..					
		F	22 50 *ca*					
5		e	(6 26 00)					
		e	6 31 30					
		eL?	6 35 ..					
		L	6 39 *to*					
			6 55 ..					
		F	7 00 *ca*					
6		e	18 00 34					Strasbourg gives dist. 8880, O 17:42:01. Distant; may be two quakes; phases not marked.
		e	18 07 ..					
		eL	18 16 ..					
		L	18 29 *to*					
			19 12 ..					
		L	19 40 ..					
		L	20 07 ..					
		L	20 29 ..					
		F	20 55 *ca*					
6		e	23 10 23					
		eL	23 14 ..					
		M	23 15 30					
		F	24 00 *ca*					
8		eL	8 16 ..					Faint traces only.
		L	8 18 *to*					
			8 27 ..					
		F	8 50 *ca*					
10		eL	1 46 ..					Barely discernible.
		F	2 00 *ca*					
10		e	19 03 30					
		eL	19 10 30					
		L?	19 36 ..					
		F	19 49 ..					

CANADA. *Dominion Observatory, Ottawa*—Continued.

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 10		e?	20 38 ..					Small traces only.
		e?	20 51 18					
		eL	20 57 ..					
		L	21 00 *to*					
		L	21 23 ..					
		F	21 40 ..					
11		e	11 30 24					
		eL	11 37 *to*					
		L	11 47 ..					
		F	12 00 *ca*					
12		eL	6 42 ..					
		L	6 46 *to*					
		L	6 53 ..					
		F	7 10 ..					
14		e	6 16 20					
		eL	6 19 45					
		F	6 49 ..					
18		*O*	8 26 16				4,680	Readings difficult to accurately interpret. Strasbourg gives P 8:31:04, dist. 7700.
		e?	8 31 00					
		P	8 34 23					
		S	8 40 48					
		i	8 41 41					
		SR2	8 44 15					
		eL	8 50 ..					
		L	9 06 ..					
		L	9 12 *to*					
			9 33 ..	20				
		L	9 34 30					
		L	10 50 ..	13				
		F	11 35 ..					
18		e?	17 16 ..					
		e?	17 20 48					
		eL	17 28 36					
		F	17 38 ..					
18		e	18 19 30					
		eL?	18 24 ..					
		L	18 46 *to*					
		L	18 51 ..					
		F	19 12 ..					
19		*O*	22 43 32				4,900	
		P	22 51 53					
		PR1	22 53 38					
		S	22 58 30					
		i	23 01 02					
		SR1	23 02 12					
		eL	23 06 ..					
		M1	23 07 30					
		M2	23 10 30					
		L	23 14 *to*					
20		L	0 10 ..					
		F	1 10 *ca*					
			HALIFAX RECORD					
		O	22 41 42				6,450	
		P	22 51 39					
		S	22 59 39					
		L	23 10 40					
		M	23 14 30					
		F						Lost.
20		eL	6 28 ..					
		F	6 44 ..					
22		e	4 02 ..					
		eL	4 05 24					
		L	4 08 ..					
		F	4 38 ..					
22		*O*	(6 54 19)				(6,100)	
		P	(7 03 56)					
		S	7 11 37					
		SR2?	7 17 06					
		eL	7 19 30					
		L	7 31 ..					
		M	7 41 30					
		M	7 44 30					
		M	7 50 ..					
		M	7 53 30					
		M	7 55 30					
		M	8 02 ..					
		L	8 07 *to*					
			9 45 ..					
		F	10 30 ..					
22		e	(21 12 38)					
		e	(21 16 23)					
		eL	21 24 ..					
		L	21 45 ..	30				
		L	21 48 ..	24				
		L	21 51 *to*					
			21 57 ..	20				
		L	21 58 *to*					
			22 03 ..	18				
		L	22 03 *to*					
			22 21 ..	17				
		L	23 02 ..					
		F	23 14 ..					

TABLE 2.—*Instrumental seismological reports, June, 1923*—Continued.

CANADA. *Dominion Observatary, Ottawa*—Continued.

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 24		eL	13 54 ..					Very heavy micros.
		F						Lost changing sheets.
24		eL	20 32 ..					
		L	20 35 ..					
		F						Micros.
25		eL	(13 15)					
		F						Do.
25		eL	22 14 *to*					
		L	22 23 ..					
		F						Do.
26		eL	2 01 ..					
		F	2 10 *ca*					
28		e?	19 04 18					
		eL	19 12 ..					
		F	19 16 ..					
30		eL	0 29 30					
		L	0 33 ..					
		F	0 50 *ca*					

CANADA. *Dominion Meteorological Service, Toronto.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 1		P	17 38 08				9,910	
		S	17 48 24					
		i	17 48 55					
		L	18 10 22					
		L	18 13 41	23				
		M	18 28 39	15		36		
		S	17 48 27					P not recorded.
		i	17 48 58	11				
		SR	17 55 08					
		L	18 10 00					
		M	18 20 37		87			Uniform waves, 18:17:38 to 18:22:45.
			to 22 30	20				
		F						Lost in next quake.
1		P?	20 32 38					May be 20:32:56.
		eS	20 39 24					
		iS	20 39 26					
		L	20 46 15					
		M	21 19 09	19		13		
		F	23 14?					
		S	20 39 28					
		i	20 39 58	15				
		eL	20 46 10	15				
		M	21 12 39	17	14			
		M	21 12 54					
2		P	1 20 49	3				Small amplitudes. North-South.
		S	1 26 22					
			or 26 26	8				
		L	1 33 15					
		F	?3 25 08					
		S	1 26 23					East-West
		L	1 33 15					
		L	1 35 52					
		L	1 40 23					
		L	1 49 15					
		L	2 05 23	23				
		F						Doubtful.
2		L_E?	13 38 45					Doubtful as to being seismic.
		Le	13 46 33					
2		L_E	23 49 11					Do.
3		F	0 31 15					
3		eL	12 34 45					Marked micros all morning.
4		L_E	21 23 08					Nothing on NS.
		L_E	21 32 52					
		L?	22 58 23					
5		L	6 38 08					
		F						Micros.
6		L_N	18 00 41					Phases not marked.
		L_N	18 23 37					
		L_N	18 35 15					
			to 57 00					
		F						Micros.
6		L_E	23 10 38					Uniform waves 23:15:15 to 23:16:37.
		L_E	23 15 15					
			to 16 37					
		F	23 55 08					
10		L_E	1 48 11					Very small.
		F	?2 01 00					
10		eL_E	19 10 23					
		F	21 11 23					
11		L	11 35 06					
		L	11 38 30					

CANADA. *Dominion Meteorological Service, Toronto*—Continued.

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 18		P	8 34 59					
		S	8 40 44					
		i	8 42 02					
		i	8 49 17					
		i	8 50 08					
		L	8 54 15					
		L	?9 00 02	30		42		
		F	10 53 00					
		i	8 30 45	5				
		i	8 33 33	3				
		i	8 34 08	5				
		P	8 34 41	5				
		P?	8 35 08	8				
		S	8 40 36					
		i	8 40 41					
		i	8 41 25					
		i	8 41 30					
		eL	8 50 00					
		eL	9 06 15	25	?27			
		F	11 06 00					
18		Le?	21 26 08					May not be seismic.
		L	21 29 00					
19		*O*	22 43 35					
		iP	22 51 51					
		S	22 58 23					
		L?	23 05 26				4,820	
		M	23 11 13	13		36		
20		F?	00 49 00					
19		P	22 51 50					
		S?	22 58 30					
22		e_E	4 02 15					Small amplitudes.
		e_E	4 02 42					
		eL_E	4 05 15					
		F	4 28 00					
22		e?	7 04 30				5,520	
		S	7 11 40				5,700	
			or 11 50					
		L	7 20 00	15				
		M	7 51 25	23	62			
		M	7 51 48					
		F	9 52 00					
		P	7 04 05					
		i	7 10 02					
		S	7 11 10					
		e	7 12 30					
		L	7 14 00					
		eL	7 20 15					
		M	8 00 15				5,430	
		M	8 00 32	17		47		
		F	9 49 00					
22		eL_E	21 24 15					Small amplitudes.
		eL_E	21 44 37	18				
		to	22 10 ..	23				
		F	23 16 00					
25		L_E	22 54 22					Small micros going on.
		eL_E	23 10 10					
		i_E	23 12 45					
		L_E	23 14 00					
		F?	23 22 00					
30		i_E	0 29 39					
		eL_E	0 32 15					
		F	0 47 00					

CANADA. *Dominion Meteorological Service, Victoria.*

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 1		P	17 35 45	4			7,400	
		S	17 44 35	11				
		L	17 57 41	20				
		M	18 09 56	18	27			
		F	20 25 56					
		P	17 35 44	7				
		S	17 44 34	10				
		L	17 53 00	26				
		M	18 00 44	10		14		
		F	20 26 51					
1		P	20 26 41	8			7,440	
		S	20 35 33	10				
		L	20 49 03	12				
		M	20 56 59	20	12			
		F	23 46 46					
		P	20 26 51	5			7,460	
		S	20 35 44	12				
		L	20 45 06	12				
		M	20 51 03	10		8		
		F	23 49 56					
2		L	1 23 01	5				May be part of following quake.
		M	1 24 01	7	2			
		L	1 23 16	5				
		M	1 24 16	10		2		

TABLE 2.—*Instrumental seismological reports, June, 1923*—Continued.

CANADA. *Dominion Meterological Service, Victoria*—Continued.

1923.		*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 2	L	2 14 56	14				
	F	3 28 36					
	L	?2 08 21	25				
	M	2 11 04	25		1		
	F	3 25 56					
4	L_E	21 55 27	25				
	L_N	21 54 12	30				
	M_N	21 54 45	25		3		
5	L	6 37 16	20				
	M	6 41 14	10	2			
	F	7 02 25					
	L	6 30 52	10				
	M	6 41 03	12		2		
	F	6 59 02					
6	L_E	17 56 17	10				
	F	20 22 42					
	P_N	17 43 05	5				
	L_N	17 56 15	10				
	F	20 27 47					
6	P	22 57 15	5			780	
	S	22 58 40	6				
	L	23 00 55	15				
	M	23 04 10	10	5			
	F	0 07 40					
	S	22 58 18	7				
	L	23 00 58	13				
	M	23 04 50	10		4		
7	F	0 11 15					
7	L	23 57 08	30				
	M	0 00 03	18	3			
	F	0 18 01					
	L_N	23 57 08	30				
18	P	8 28 13	5			2,690	*NS. component not recording from 13th to 23d;* changing to permanent pier.
	S	8 32 33	7				
	L	8 38 07	10				
	M	8 38 35	10	12			
	F	10 42 27					
19	P	22 48 31	5				
	L	22 52 50	10				
	M	22 56 19	10	38			
20	F	1 10 40					
20	L	6 14 10	20				
	M	6 24 19	12	2			
	F	6 28 40					
22	P	3 52 39	7			440	
	S & L	3 53 27	10				
	M	3 54 29	8	8			
	F	4 12 39					
22	P	7 02 29	5			4,920	
	S	7 09 07	9				
	L	7 20 57	12				
	M	7 46 05	18	62			
	F	9 50 34					
22	P	21 10 11	5				
	L	21 28 20	22				
	M	21 33 07	8	1			
	F	22 04 44					
30	P	0 08 11	6				
	L	0 12 09	8				
	M	0 14 44	16	2			
	F	0 41 51					
	L	0 12 09					
	M	0 14 41			1		
	F	0 35 41					

Reports for June, 1923, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.
DISTRICT OF COLUMBIA. *Georgetown University*, Washington.
MASSACHUSETTS. *Harvard University*, Cambridge.
MISSOURI. *St. Louis University*, St. Louis.
NEW YORK. *Cornell University*, Ithaca; *Fordham University*, New York.
CANAL ZONE. *Panama Canal*, Balboa Heights.

TABLE 3.—*Late reports* (*instrumental*).

NEW YORK. *Cornell University, Ithaca.*

1923.		*H. m. s.*	*Sec.*	μ	μ	*Km.*
Apr. 13	e	15 51 ..				
	e	15 55 48				
	e	15 58 36				
	L	16 04 ..	24			
	F	18 01 ..				
19	e	3 32 ..				
	e	3 35 ..				
	e	3 54 ..				
	L	4 18 ..	28			
	L	4 31 ..	24			
	F	5 06 ..				
23	L	4 01 ..	24			
	L	4 28 ..	15			
	F	4 44 ..				
24	e	23 05 30	4			
	F	23 28 ..				
25	e	19 50 24				
	L	19 53 24				
	F	20 17 ..				
29	eL	2 49 ..				
	L	2 52 ..	11			
	F	3 07 ..				
May 2	e	16 38 ..				
	eL	16 43 ..				
	L	16 43 48	11			
	F	17 05 ..				
4	eP	16 35 44				
	S	16 43 04				
	i	16 45 33				
	e	16 46 39				
	L	16 51 ..	30			
	L	16 54 18	13			
	F	18 32 ..				
4	e	22 38 12				
	e	22 47 06				
	L	22 59 ..	16			
	F	23 15 ..				
23	L	23 14 ..	24			
	F	23 59 ..				
30	L	9 05 30				
	F	9 12 ..				
30	e	18 15 18				
	L	18 34 ..				
	F	18 45 ..				

CANADA. *Dominion Meteorological Service, Toronto.*

1923.		*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 2	L	16 45 30					Milne. Recorded on Milne-Shaw, but no cutoff.
	M	16 45 48		*300			
4	P	16 37 54					Milne.
	S	16 43 42					
	i	16 47 54					
	L	16 54 06					
	M	16 58 24		*5000			
	F	20 10 24					Milne-Shaw.
	M1	16 51 15	9	49			Early phases lost—working in seismograph room.
	M8	16 57 15	15	181			M_E ampl., 152μ. Smaller L waves 16:25:30, period 15 to 18 sec. F in micros.
4	P	22 38 29	4			7,390	Milne-Shaw. Small micros previous to P.
	S	22 47 18					
	i	22 47 26					
	e	22 56 15	23				
	M1	22 48 11	8	11			
	M2	23 00 38	23	37			
	L	23 00 45					
	L	23 01 05					
5	F	?0 49 05					
8	e_E	19 20 15					Milne-Shaw. Very small amlitudes.
	e_E	19 22 42					
	L_E	19 32 20					
	L_E	19 34 08					
	F_E	20 17 30					
	e_N	19 23 20					
	L_N	19 34 15					
	F_N	20 17 30					

TABLE 3.—*Late reports (instrumental)*—Continued.

CANADA. *Meteorological Servtce, Toronto*—Continued.

1923.			H. m. s.	Sec.	μ	μ	Km.	
May 10		e_N	4 01 00					Milne-Shaw. Small amplitude.
		L_N?	4 10 00					
			to 25 15					
		L_N	4 45 38	18				
		F_N	?6 10 00					
11		e_E	8 44 30					Minute small waves.
		L_E	9 08 00					
		F	10 05 00					
12		i_N	1 39 38					Milne-Shaw. EW not so much affected.
		i_N	1 42 42					
		i_N	1 43 19					
		e_N	1 51 22					
		S_N	1 52 53	7				
		eL_N	2 02 20	23				
		L	2 34 43	30				
		M	2 46 15					
			to 48 10			21		
		F	3 38 37					
15		P_E	21 53 52					Milne-Shaw.
		S_E	22 03 31					
		S_N	22 03 32					
		L_E	22 19 00					Very small amplitudes.
		L_E	22 31 35	15				
		F_E	23 35 35					
23		P_E	22 48 28				7,460	Milne-Shaw.
		eS_E	22 57 21					
		eS_E	22 57 32					
		eL_E	23 05 08					
		L_E	23 13 18					
			to 16 15					
		M_E	23 14 48	20	48			
24		F	2 22 45					
23		P_N	22 48 33				7,390	
		S_N	22 57 22					
		eL_N	23 04 01					
		L_N	23 05 00					Uniform L waves 23:13:18 to 23:16:15.
		M	23 14 52	19–23		27		
24		F	2 15 37					Milne-Shaw.
25		L_E	22 43 37					Times doubtful; no cutoff. Very small amplitudes.
		L_E	22 45 40					
		L_E	22 51 53					
		L_E	23 18 10					
			to 24 00					
26		F_E	0 58 15					
26		L	3 45 36					Milne.
		L	4 09 42					
			to 12 42		*100			
		F						
26		L	9 36 12					Milne.
		L	10 01 12		*50			
		F	10 07 54					
28		L	2 36 48					
		L	2 51 00					
		eL	3 08 06					
		M	3 11 03		*300			
		F	4 02 00					
30		i_N	?8 44 15					Milne-Shaw. Micros precede 8:48:32.
		P_N or S_N	8 48 32					
		L_N	8 52 45	17				
		L_N	8 57 15					
		L_N	9 00 30					
		L_N	9 06 00	15				
			to 07 45			12		
		F	9 56 00					
		P_E	?8 48 34					
		S_E	8 58 08	8				
		L_E	9 00 22					
		L_E	9 08 02	15	8			
		F_E						Micros.
30		e_N	18 14 52					Milne-Shaw.
		e_N	18 18 55					
		L_N	18 31 15					
			to 34 00					
		M_N	18 32 56	17		20		
		F						Micros.

CANADA. *Meteorological Service, Toronto*—Continued.

1923.			H. m. s.	Sec.	μ	μ	Km.	
May 31		L_N	6 49 00					Through waves of disturbance.
		L_N	6 58 08					
		F	7 11 15					Milne-Shaw.
31		*O*	22 05 47				3,620	Milne-Shaw.
		P_E	22 12 37	5				
		$PR1_E$	22 17 10					
		iS_E	22 18 02					Uniform waves 22:22 to 22:37:30.
		eL_E	22 21 45		10			
		L_E	22 22 *to*	15				
			22 30 ..	19				
		F	23 16 00					
		i_N	22 16 17					P not recorded.
		e_N	22 17 08					
		Sn?	22 18 02					
		L_N	22 22 23					Amplitudes very small.
		F_N	23 08 00					
31		S	22 17 48					Milne.

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

1923.			H. m. s.	Sec.	μ	μ	Km.	
May 2		e_N	16 39 30					EW record obscured by overlap.
		M_N	16 41 54	8		10		
		F_N	16 49 ..					
4		*O*	16 26 40				3,660	Paper changed between 17:06:21 and 17:16:21; EW record lost after this through overlap.
		P_E	16 33 36					
		iP_N	16 33 33					
		iPR_E	16 34 53					
		PR_N	16 34 47					
		e_N	16 35 58					
		iS	16 39 00	20				
		$SR1_E$	16 40 55	20				
		$SR1_N$	16 40 52					
		$SR2_N$	16 41 11	30				
		$L1_E$	16 41 37	13				
		$L2_E$	16 42 30	10				
		L_N	16 42 45	20				
		M_E	16 44 45	8	151			
		M_N	16 45 26	20		730		
		C_E	16 47 ..					
		F_N	19 52 ..					
4		e_N	22 51 45					E record lost through overlap.
		M_N	23 39 30	16		6		
5		F_N	0 19 45					
5		e	15 19 00					
		M_E	15 20 40	9	14			
		M_N	15 20 30	9		17		
		F	15 27 ..					
12		e_E	2 09 40					
		M_E	2 13 10	25	15			
		F_E	2 19 ..					
15		e	21 48 ..					
		F_E	21 54 ..					
		F_N	22 02 ..					
23		*O*	22 37 26				4,630	E record obscured by overlap.
		P_N	22 45 29					
		S_N	22 51 51	18				
		$L1_N$	22 56 38					
		$L2_N$	22 57 39					
		$L3_N$	23 00 02	19				
		$M1_N$	23 01 24	18		134		
		$M2_N$	23 09 36	15		57		
24		F_N	1 26 ..					
26		e	9 09 ..					
		F	9 19 ..					
28		e_N	8 55 ..	6		7		
		F_N	9 03 ..					
30		e_N	9 10 ..	25				
		F_N	9 20 ..					
30		e_N	18 17 00	9		6		
		F_N	18 39 ..					
31		e_E	22 57 ..	22	5			
		e_N	22 58 ..	17		1		
		F	23 07 ..					

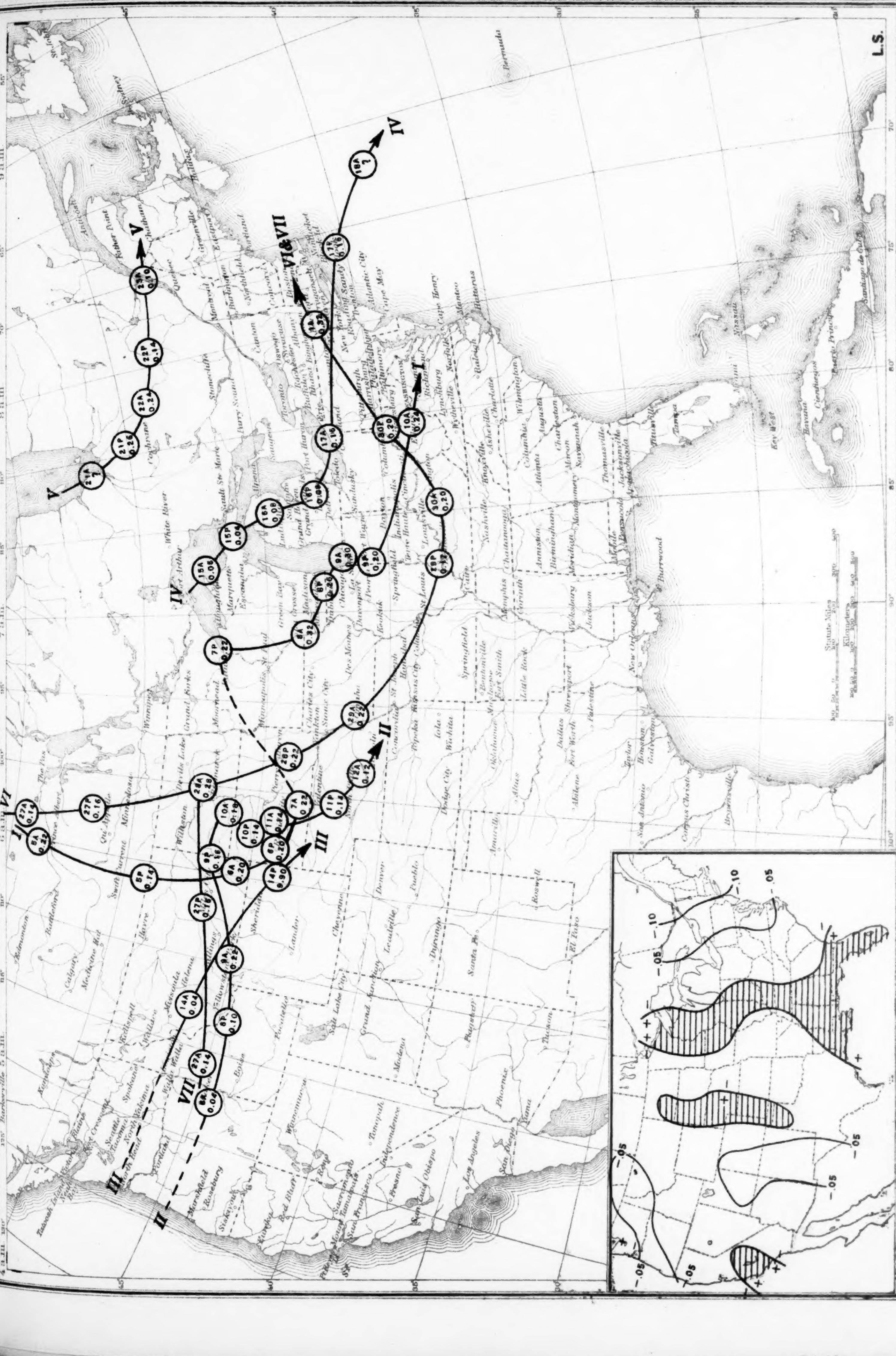

Chart I. Tracks of Centers of Anticyclones, June, 1923. (Inset) Departure of Monthly Mean Pressure from Normal.
(Plotted by Wilfred P. Day.)

Chart II. Tracks of Centers of Cyclones, June, 1923. (Inset) Change in Mean Pressure from Preceding Month.

(Plotted by Wilfred P. Day.)

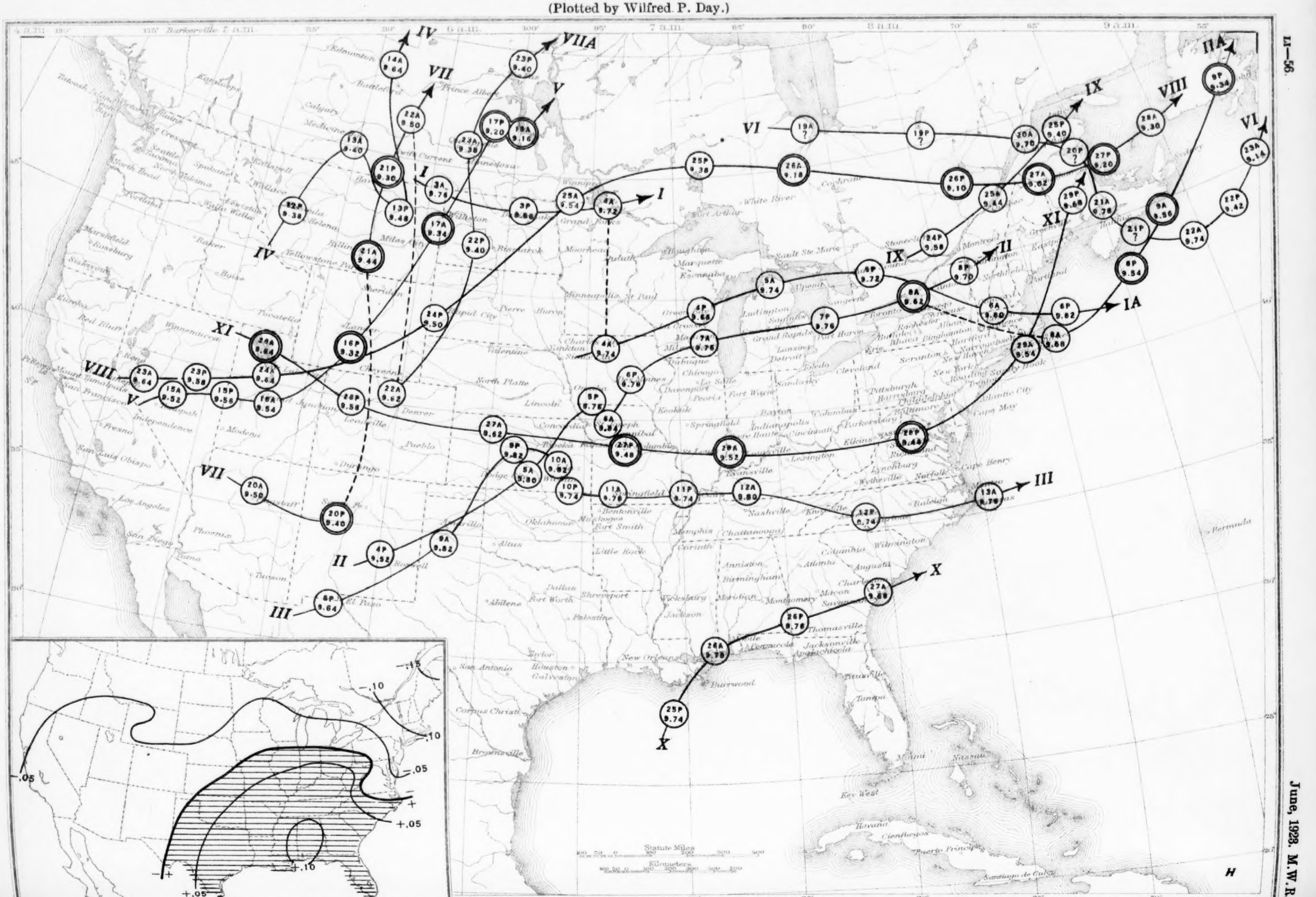

Chart III. Departure (°F.) of the Mean Temperature from the Normal, June, 1923.

Chart III. Departure (°F.) of the Mean Temperature from the Normal, June, 1923.

Chart IV. Total Precipitation, Inches, June, 1923. (Inset) Departure of Precipitation from Normal.

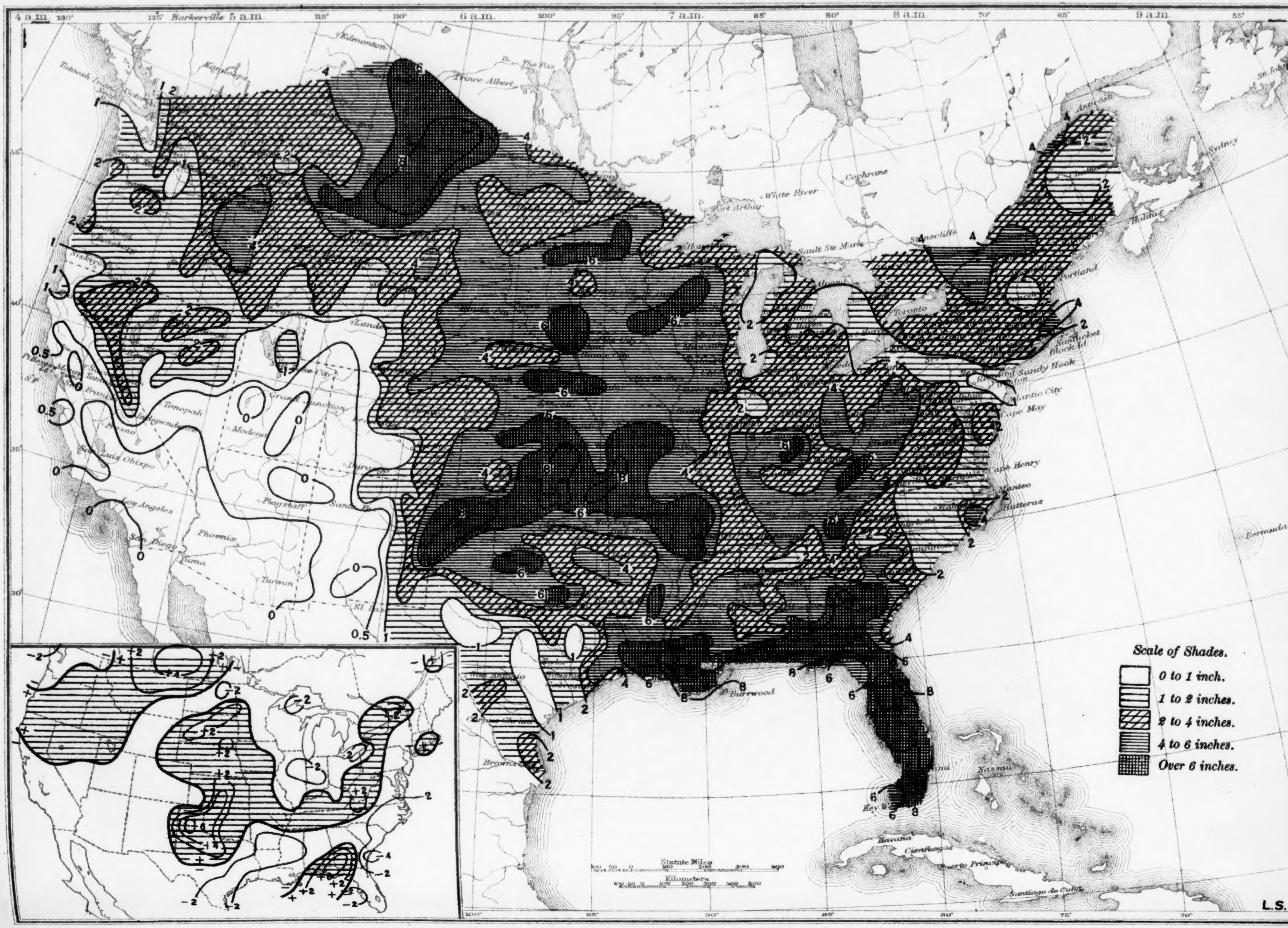

Chart V. Percentage of Clear Sky between Sunrise and Sunset, June, 1923.

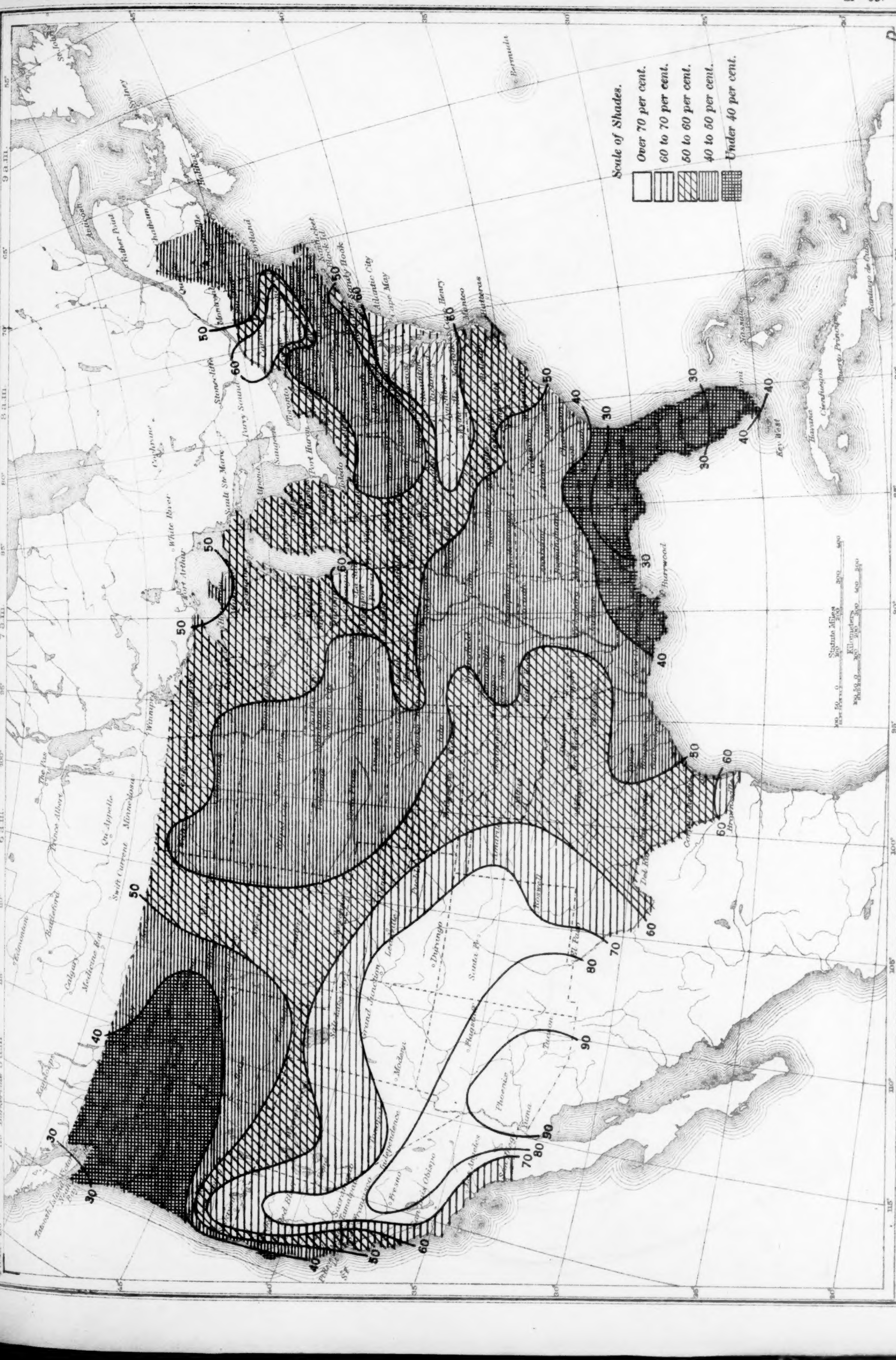

Chart VI. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, June, 1923.

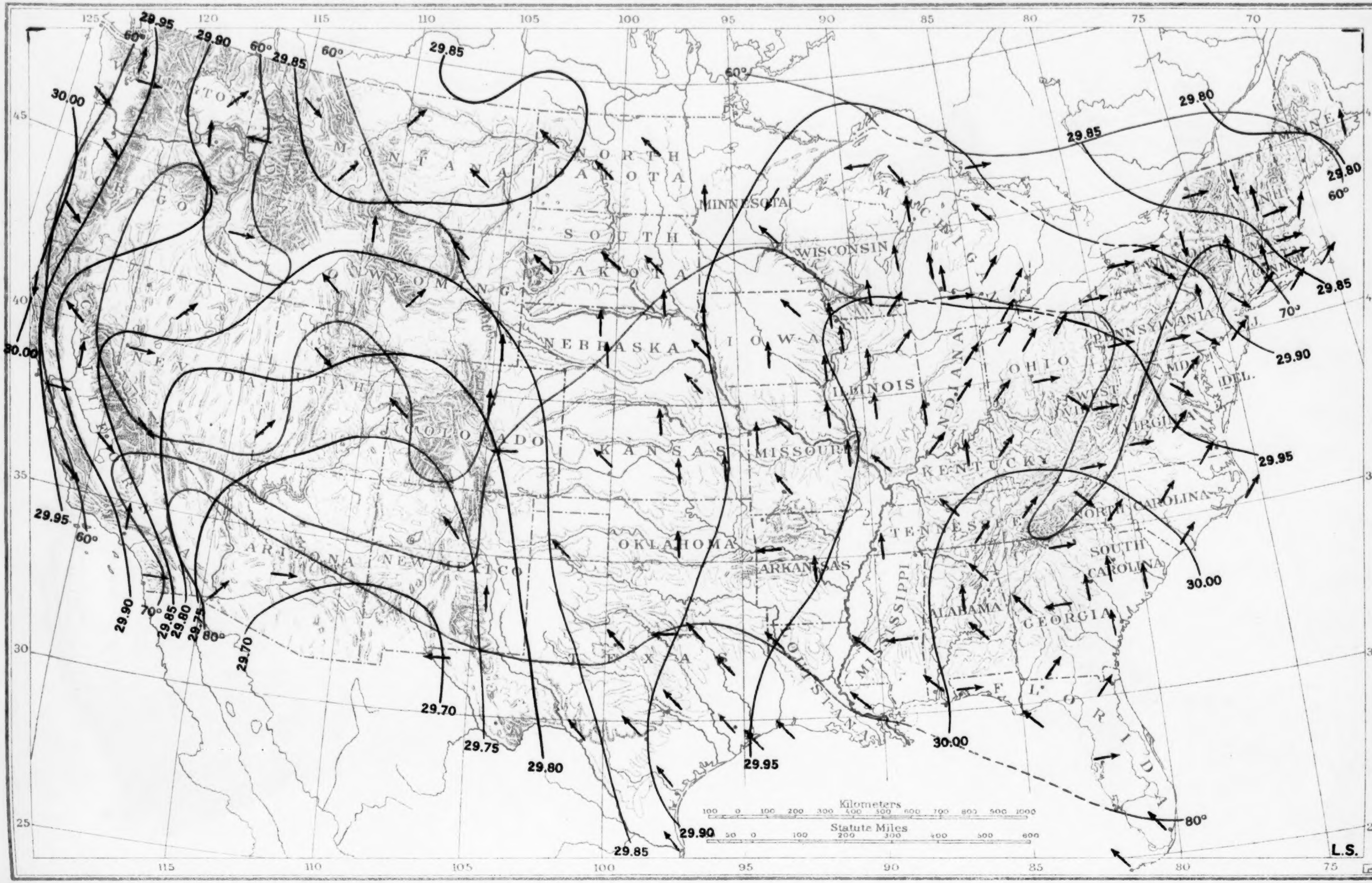

Chart VIII. Weather Map of North Atlantic Ocean, June 23, 1923.
(Plotted by F. A. Young.)

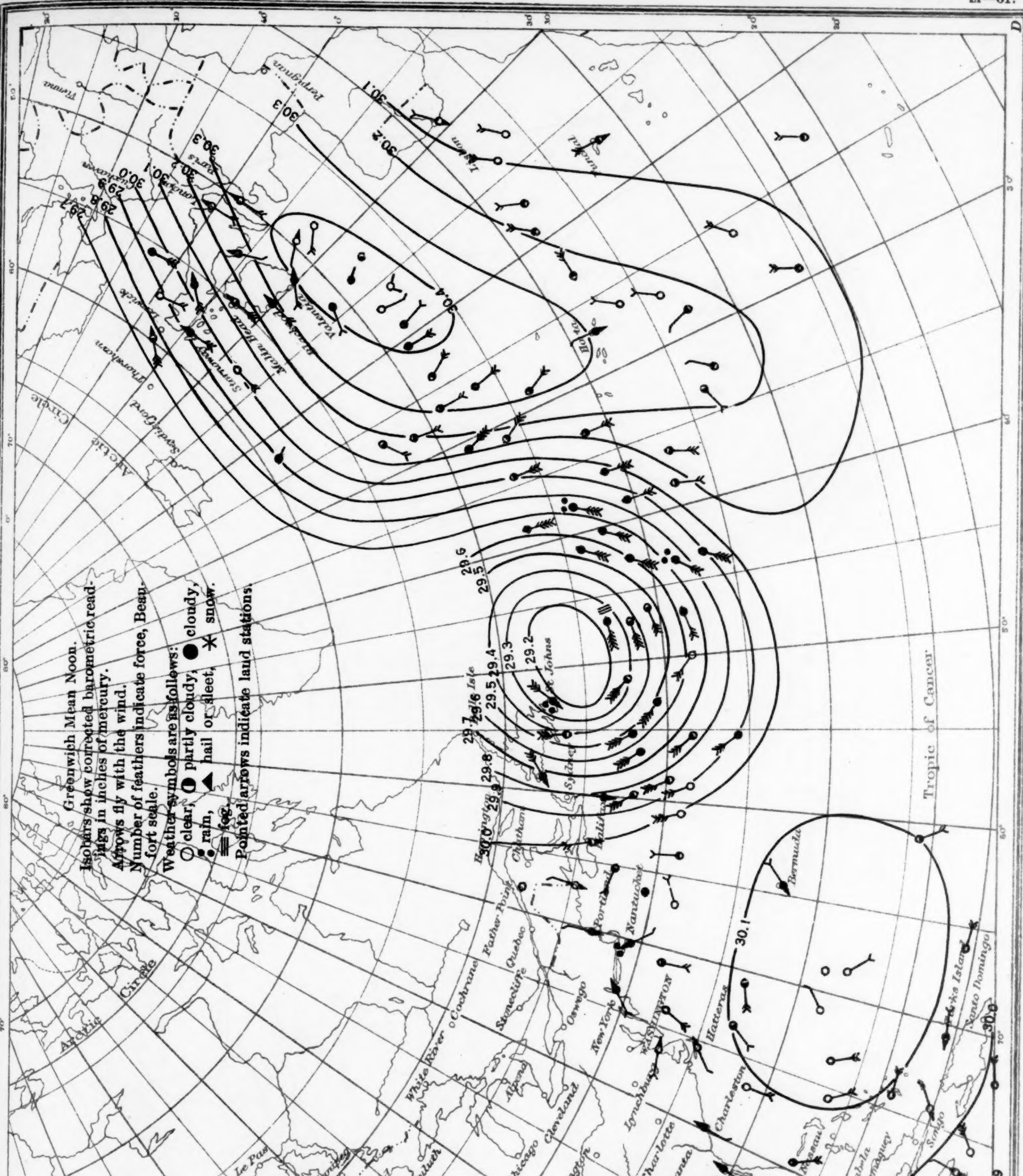

Chart VIII. Weather Map of North Atlantic Ocean, June 23, 1923.
(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, June 24, 1923.

(Plotted by F. A. Young.)

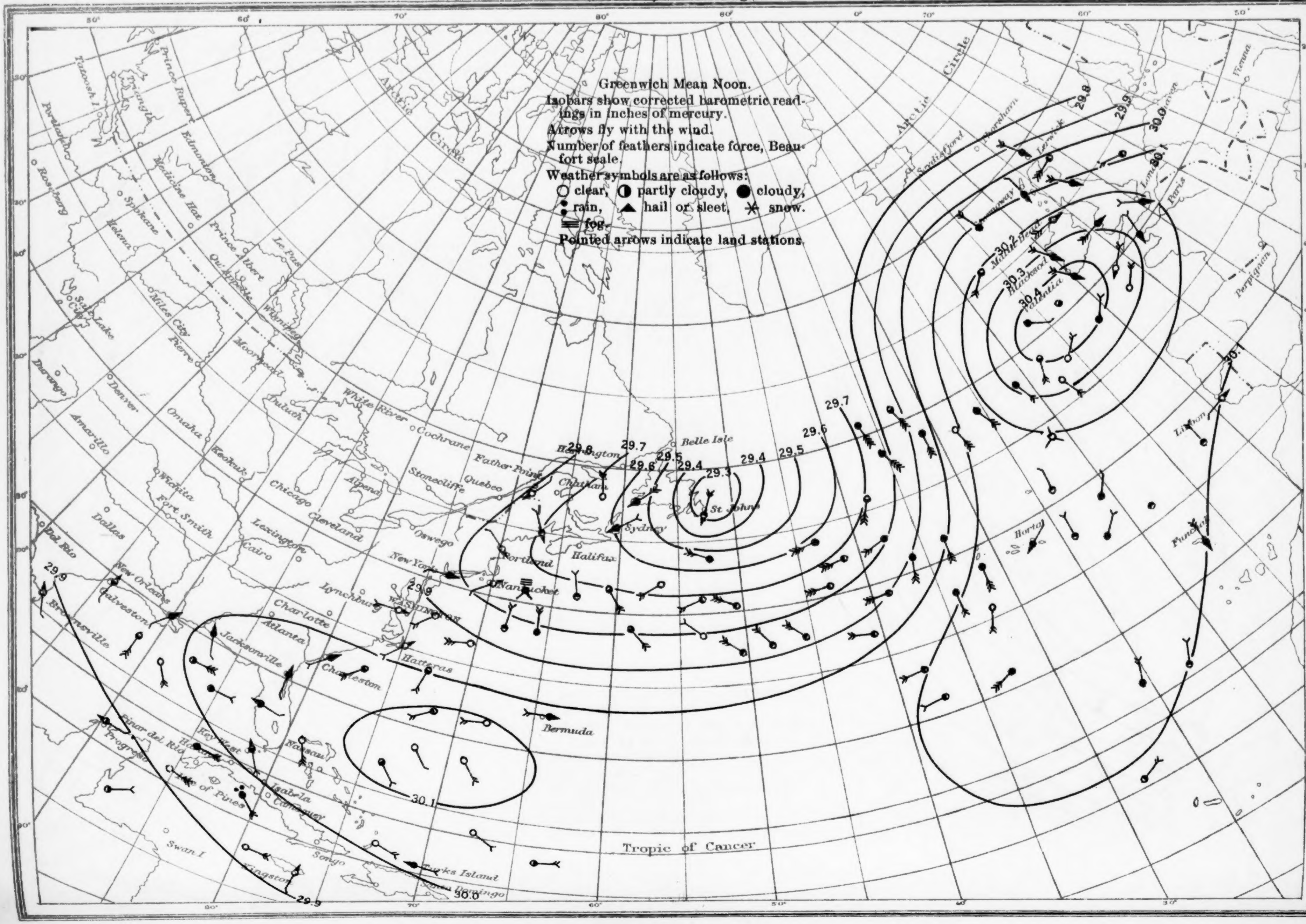

Chart X. Weather Map of North Atlantic Ocean, June 25, 1923.

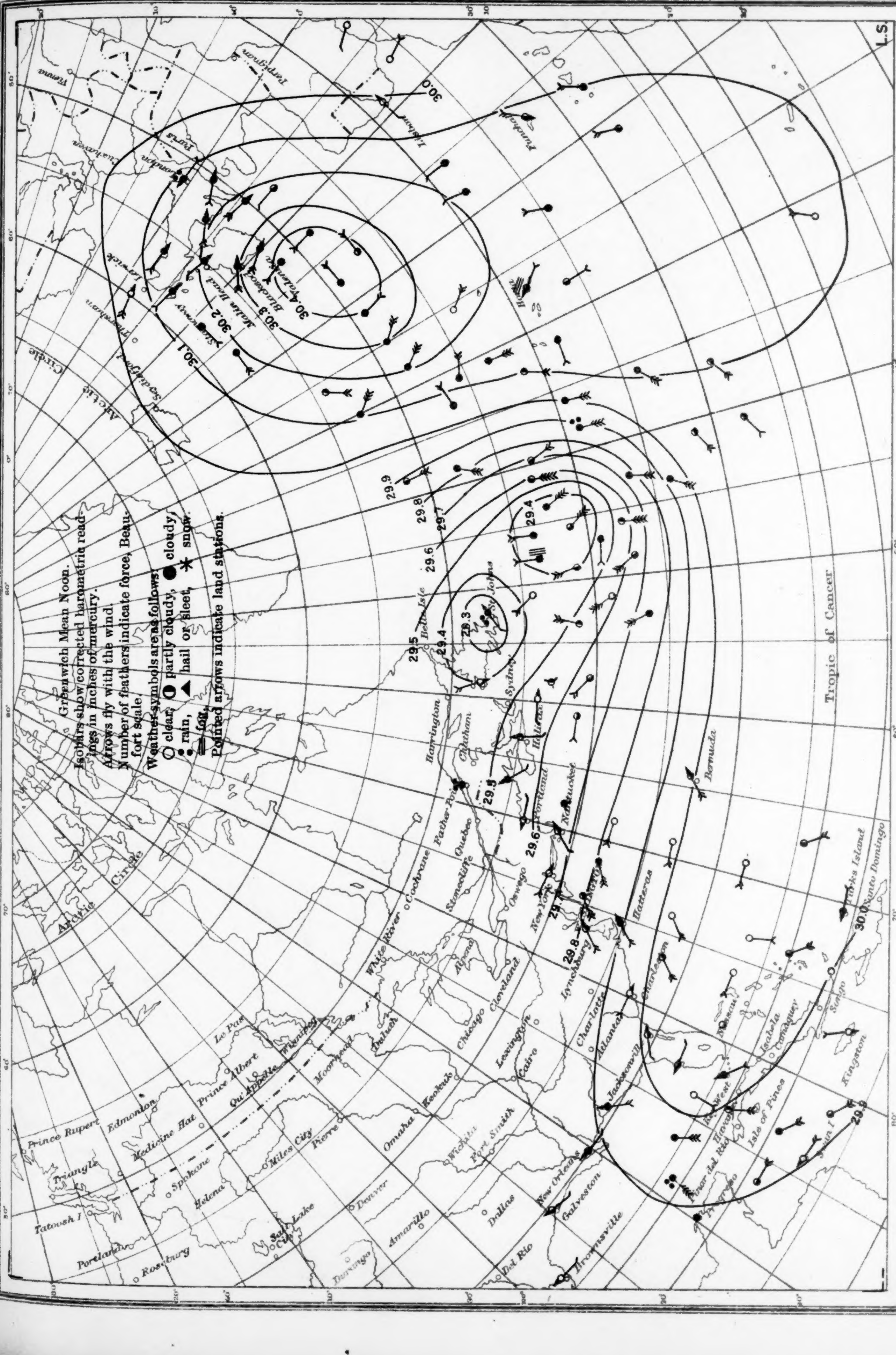

Chart X. Weather Map of North Atlantic Ocean, June 25, 1923.
(Plotted by F. A. Young.)

Chart XI. Weather Map of North Atlantic Ocean, June 26, 1923.

(Plotted by F. A. Young.)